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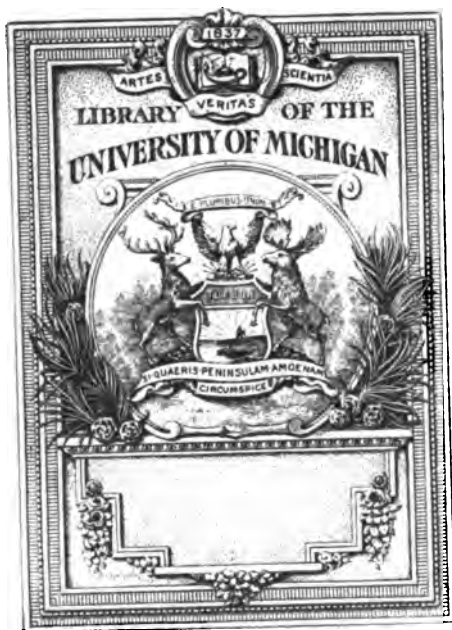
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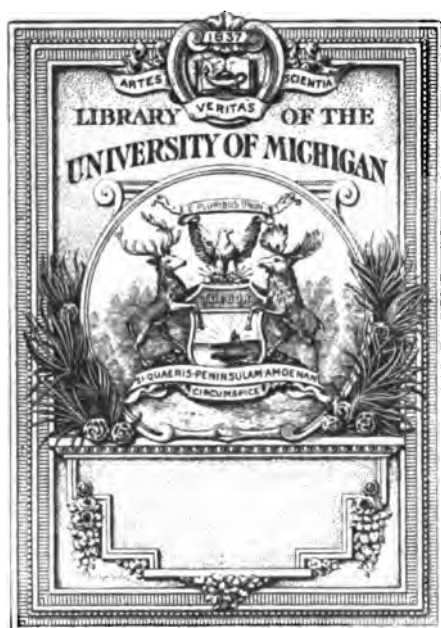
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JOURNAL
OF THE
Elisha Mitchell Scientific Society

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JOURNAL
OF THE
ELISHA MITCHELL SCIENTIFIC SOCIETY.

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VOL. XXI

MARCH, 1905

NO. 1

A DESCRIPTIVE CATALOGUE OF THE MAMMALS
OF NORTH CAROLINA, EXCLUSIVE
OF THE CETACEA.

BY C. S. BRIMLEY.

This list is intended to represent our present knowledge of the occurrence and distribution of the land Mammals found within the limits of the State of North Carolina, together with keys to the orders, families and genera, and brief descriptions of the various species.

The keys are mainly adapted from Mr. G. S. Miller's "Key to the Land Mammals of Northeastern North America," but some use has also been made of Dr. Jordan's well known "Manual of the Vertebrates."

The material on which this list is based is as follows:

I. COLLECTIONS OF MAMMALS MADE IN NORTH CAROLINA.

1. A collection of the smaller mammals of Bertie county made for the author and his brother by Mr. T. A. Smithwick, of Walke, and Mr. J. W. P. Smithwick, of Sans Souci, in 1892, 1893, and 1894. The collection comprised nineteen species, the largest being the Flying Squirrel and a list of them was published by the author in the *American Naturalist*, March, 1897.

2. Specimens received from Mr. J. S. Cairns (now deceased),

of Weaverville, Buncombe county, comprising sixteen species of the smaller mammals of that region, the largest being the Red Squirrel. A Star-nosed Mole was also received from Mrs. Cairns after her husband's death. (Collecting was done from about 1891 to 1894.)

3. In 1872 Dr. Elliott Coues collected a number of natural history specimens near Fort Macon and published notes on them, eighteen species mainly of the larger mammals being observed.

4. In 1897 Mr. R. T. Young collected small mammals in Currituck and Perquimans counties. The results of his collecting were published by Mr. S. N. Rhoads.

5. Collection from Roan Mt. in 1897 made by Mr. S. N. Rhoads.

6. Collections from Roan Mt. in 1887, 1892, 1893 and 1894 made by and for the United States Biological Survey.

7. Skulls and skins of a number of furbearing mammals trapped by Mr. Walton E. Stone from 1897 to 1900 in the neighborhood of Rosebay, Hyde county.

8. From about 1888 to 1900 my brother and myself collected small mammals near Raleigh, in Wake county, a list of which was published in the *American Naturalist*, May 1897.

9. Specimens received by the State Museum at Raleigh from various parts of the State. These have been mainly of the larger species.

II. RECORDS OF NORTH CAROLINA MAMMALS.

Records of North Carolina mammals scattered through the papers of American Mammalogists. (A list of all papers consulted by the author will be found at the end of the catalogue.)

III. LISTS OF THE LARGER AND BETTER KNOWN MAMMALS.

Lists of the larger and better known mammals of their vicinity received from Messrs. J. H. Armfield, Guilford county;

R. W. Collett, Cherokee county; R. D. Foxhall, Edgecombe county; N. W. Fain, Buncombe county; K. E. Shore, Forsyth county; T. A. Smithwick, Bertie county; Dr. J. W. P. Smithwick, Lenoir county; Miss Maggie Wicker, Moore county; and Dr. Donald Wilson, Cherokee county, to all of whom I am very much indebted for the information furnished.

Thanks are also due to Messrs. H. H. Brimley, Curator State Museum, Raleigh, N. C.; Dr. Witmer Stone, Academy of Natural Sciences, Philadelphia; G. S. Miller, Jr., United States National Museum; S. N. Rhoads, Philadelphia; Dr. J. A. Allen, American Museum of Natural History, New York; Outram Bangs, Boston, Mass.; and especially to Dr. C. Hart Merriam, Chief of the United States Biological Survey, for information given and assistance rendered.

The class Mammalia comprises warm blooded vertebrates, usually clothed with hair and never with feathers. A number of other characteristics define the class, but the warm blood distinguishes it from all other classes of animals except the birds and these are distinguished from mammals by the presence of feathers.

In the following catalogue the orders and families are arranged in the same sequence as in *Jordan's Manual.

Sixty-six species and subspecies are credited herein to North Carolina, and are numbered serially from 1 to 66. Nine other species, not yet known to occur are added in brackets without numbers, in their proper places. Some of the forms included may be really the same as other allied forms also included, or but slightly different, but I have tried to use as good judgment as was possible in the matter.

KEY TO THE ORDERS OF LAND MAMMALS OCCURRING IN NORTH CAROLINA.

- a. Female generally (always in our species) provided with a pouch in which the young are carried for a time

*Manual of the Vertebrates of the Northern United States, by D. S. Jordan, Chicago, 1899, A. O. McClurg & Co.

- after birth. Order I. Marsupialia. (Opossums, etc.)
- aa. Females without external pouch for carrying the young.
 - b. Fore limbs modified to serve as wings. Order II. Cheiroptera (Bats).
 - bb. Fore limbs not modified to serve as wings.
 - c. Toes provided with hoofs. Order III. Ungulata. (Deer, Cattle, etc.)
 - cc. Toes not furnished with hoofs, but with claws of some sort.
 - d. Front teeth chisel shaped and separated from jaw teeth by a wide space. Order IV. Glires. (Squirrels, Rats, Mice, Rabbits, etc.)
 - dd. Front teeth not chisel shaped, tooth row nearly or quite continuous.
 - e. Brain large, well developed. In our species size large, eyes well developed, muzzle not greatly elongated. Order V. Ferae. (The flesh eaters, Cats, Dogs, Foxes, Bears, etc.)
 - ee. Brain small, not highly developed. In our species size small, eyes small or rudimentary, muzzle elongate. Order VI. Insectivora. (Moles and Shrews.)

ORDER I. MARSUPIALIA.

FAMILY DIDELPHIDAE (THE OPOSSUMS).

The members of this family, which is the only one represented in America, have 50 teeth, a prehensile tail, and the hind feet with five toes each, the outer one of which is clawless and thumb-like. Our only genus is,

GENUS DIDELPHIS, L.

1. *Didelphis virginiana*, Kerr. Common Opossum. Blackish

varied with grayish white, ears naked, leathery. *L. 28. T. 11. The Opossum is found throughout the whole State even in the most thickly settled portions.

ORDER II. GLIRES.

(THE RODENTS OR GNAWERS.)

Front teeth long, chisel-shaped; cheek teeth broad, short, flat-crowned, a wide toothless space between the front teeth and cheek teeth.

Five of the American families of this group are found in North Carolina, and may be distinguished as follows:

FAMILIES OF GLIRES.

- a. Upper front teeth four, the second pair small and placed directly behind the first pair. Family Leporidae. (Hares and Rabbits.)
- aa. Upper front teeth two.
 - b. Tail very broad, flattened from above downwards. Family Castoridae. (Beavers.)
 - bb. Tail round or flattened from side to side.
 - c. At least four well developed grinding teeth on each side in each jaw. Tail bushy. Family Sciuridae. (Squirrels.)
 - cc. Never more than three well developed grinding teeth in each jaw, tail close haired or nearly naked.
 - d. Hind feet not greatly elongated. Family Muridae. (Rats and Mice.)
 - dd. Hind feet and tail greatly elongated. Family Dipodidae. (Jumping Mice.)

*L=total length of animal from tip of nose to end of tail bone (not to end of hairs on end of tail).

T=length of tail from root to end of vertebrae (not to end of hairs).
Measurements are in inches.

FAMILY LEPORIDAE. (THE RABBITS.)

Upper front teeth four, the second pair small and placed directly behind the others, which are grooved in front, teeth 28 in all. Tail short, recurved, eyes large, ears long, soles furred. The family includes the single genus *Lepus*, two species of which are found in North Carolina.

GENUS *LEPUS*, L.

a. *Post orbital process fused with the skull* (subgenus *Limnolagus*).

2. *L. palustris*, Bachm. Marsh Rabbit Yellowish brown: tail very short, ashly not white, below. L. 17. T. 1. Ear $2\frac{1}{2}$. Found in the marshes of the eastern part of the State, extending as far north as Hyde county and as far east as Lenoir county.

aa. *Post orbital processes not fused with the skull, but touching it behind enclosing a foramen* (subgenus *Sylvilagus*.)

3. *L. floridanus mollurus* Thomas. Cottontail Rabbit. Much grayer than the preceding, the tail twice as long, cottony white below. L. 18. T. 2 Ear $2\frac{1}{2}$, hind foot $3\frac{3}{4}$. Common throughout the whole State.

(The Southern Varying Hare, *Lepus americanus virginianus* Harlan, a member of a third subgenus *Lepus*, which has the post orbital processes free behind, occurs in the Alleghanies as far south as Virginia. This is rusty brown above, the tail dull yellowish or whitish below. L. 19. T. 2. Ear 3. Hind foot $5\frac{1}{2}$.)

FAMILY DIPODIDAE (JERBOAS AND JUMPING MICE).

Front teeth two in each jaw, in our species grooved in front, cheek teeth usually four on each side in upper jaw (three in one species). There is only one American genus, two species of which occur in the State.

GENUS ZAPUS, COUES.

a. *A small, probably useless, tooth in front of first well developed grinder in upper jaw. Teeth 18 in number. Tail in our species brown to the extreme tip (subgenus Zapus).*

4. *Z. hudsonius americanus* Barton. Southern Jumping Mouse. Back dusky brown faintly tinged with reddish buff, sides reddish buff very slightly grizzled; under parts white tinged with yellowish. L. $7\frac{1}{2}$. T. $4\frac{1}{2}$. Hind foot $1\frac{1}{8}$. Only known in this State from Wake county (Raleigh), the most southern locality it has been recorded from.

5. *Z. hudsonius hudsonius* Zimmermann. Northern Jumping Mouse. Back yellowish brown; sides light grayish buff, slightly sprinkled with black, belly white tinged with yellowish. L. $8\frac{1}{2}$. T. $5\frac{1}{8}$. Hind foot 1 3-16. Known only in this State from Roan Mt., the most southern locality from which it is known.

aa. *No small tooth in front of first well developed grinder in upper jaw, teeth 16; tail more or less tipped with white (subgenus Napaezapus).*

6. *Z. insignis roanensis* Preble. Roan Mt. Jumping Mouse. Sides bright tawny ochraceous; back much darker. Under parts pure white. Tail more or less tipped with white. L. $8\frac{3}{4}$. T. $5\frac{1}{8}$. Hind foot 1 3-16. Known only from the evergreen forests of Roan Mt.

FAMILY MURIDAE.

Front teeth two, cheek teeth never more than three in each jaw. In the species that occur within our limits the hind feet and legs are never greatly elongated for jumping. Ten of the numerous genera occur in the State, one genus with its three or four species being an introduction from the old world, the remaining nine genera are all natives.

a. Grinding teeth with tubercles arranged in three transverse rows, very distinct in teeth of upper jaw (subfam. Murinae, Old World Rats and Mice).

GENUS MYS.

- aa. Grinding teeth with tubercles in two rows or without distinct tubercles of any kind.
- b. Crowns of grinding teeth with tubercles in two rows.
- bb. Crowns of grinding teeth divided into loops or triangles, (subfam. Cricetinae, American Rats and Mice).
- c. Upper front teeth grooved, size small.

GENUS REITHRODONTOMYS.

- cc. Upper front teeth not grooved.

- d. Tail as long as or longer than head and body, total length of adults 9 inches or over, fur coarse.

GENUS ORYZOMYS.

- dd. Tail much shorter than head and body, total length of adults $9\frac{1}{2}$ inches or over, form stout, fur coarse.

GENUS SIGMODON.

- ddd. Total length of adults under 8 inches, fur fine and soft, belly white. Tail as long as head and body or somewhat shorter.

GENUS PEROMYSCUS.

- e. Upper front teeth narrow, compressed; tail always eyes and ears large, belly white, (subfam. Neotominae, Wood Rats and Cave Rats).

GENUS NEOTOMA.

- ee. Upper front teeth broad; tail usually short; ears and eyes small; belly generally not white (subfam. Microtinae, Voles and Lemmings).

- f. Lower front teeth short, their roots terminating on inner side of grinders (upper front teeth grooved in our species).

GENUS SYNAPTOMYS.

- ff. Lower front teeth long, their roots extending under posterior grinding teeth into outer side of jaw.

- g. Tail flattened sideways, size large.

GENUS FIBER.

- gg. Tail round, size small or medium.

- h. Grinding teeth without roots (prongs).

GENUS MICROTUS.

- hh. Grinding teeth with roots (prongs) in adults.

GENUS EVOTOMYS.

GENUS MUS, L. (Introduced Rats and Mice).

7. *Mus musculus* L. House Mouse. Brownish gray, paler below. L. $6\frac{3}{4}$. T. $3\frac{3}{8}$. Very common in houses and largely so in fields also.

8. *M. alexandrinus* Geoff, St. Hil. Roof Rat. Brown, under parts white. Tail as long or longer than head and body; about size of *Mus rattus*. Common at Raleigh and probably the common house rat of the whole State.

(*M. rattus* L. Black Rat. Blue black darker on the back, more slaty on the belly. L. $15\frac{3}{4}$. T. $8\frac{1}{2}$. Tail as in the Roof Rat about as long as head and body. The Black Rat was formerly wide spread in the eastern United States, but has been in the north almost exterminated by the Brown Rat. It very probably occurs or has occurred in the past, but we have no records.)

9. *M. norvegicus* Erxl. Brown Rat, Wharf Rat. Brownish above, grayish below, tail shorter than head and body. L. $15\frac{3}{4}$. T. $7\frac{1}{8}$. The common house rat of the north as *M. alexandrinus* is of the south, but the only record we have for North Carolina is that of Coues, who says they were common in the vicinity of Fort Macon in 1870.

GENUS SIGMODON (Cotton Rats).

10. *S. hispidus* Say & Ord. Cotton Rat. Upper parts brown coarsely and irregularly varied with brownish black, brownish white below. Form short and stout. L. $10\frac{1}{2}$. T. 4. Only recorded in this State from Raleigh, where it is abundant, but undoubtedly occurs commonly throughout the greater part of eastern North Carolina.

GENUS REITHRODONTOMYS, GIGLIOLI (Harvest Mice).

11. *Reithrodontomys lecontei lecontei* Aud & Bach. Harvest Mouse. Light brown above, whitish beneath. L. 5. T. $2\frac{3}{8}$. Much like a House Mouse but smaller and distinguished by its grooved front teeth and furry ears. Has only been taken

in Wake and Bertie counties, where it is common, but doubtless occurs throughout the greater part of the State.

(*Reithrodontomys lecontei impiger* Bangs. Virginia Harvest Mouse. Russet brown above, dull white below. L. $4\frac{1}{2}$. T. 2. Common at White Sulphur Springs, West Virginia, and therefore probably occurs in the northeastern part of the State but seems scarcely distinct from the preceding.)

GENUS PEROMYSCUS, GLOGER (Deer Mice).

12. *P. leucopus* Raf. Deer Mouse. Tail 40 to 45 per cent. of total length. Chestnut brown above, pure white below sharply defined against the color of the sides, tail bicolor. Young bluish gray. L. $6\frac{1}{2}$. T. 3. Hind foot 1 3-16. Common in Wake, Bertie, Buncombe, Perquimans and Currituck counties, and probably throughout the whole State.

13. *P. canadensis nubiterrae* Rhoads. Cloudland Deer Mouse. Dull brownish above, white below, the two colors sharply defined; tail as long as head and body with a tuft of hairs at tip. L. $6\frac{1}{2}$. T. $3\frac{1}{2}$. Only known from Roan Mt. in Mitchell county.

14. *P. gossypinus* Leconte. Cotton Mouse. Dark brown above with broad darker dorsal band, under parts gray, feet and hands grayish white. Young blackish slate gray above, slate gray beneath. L. 7. T. $2\frac{7}{8}$. This species replaces its smaller relative (*P. leucopus*) in the southeastern United States and in this State most probably occurs throughout the whole southeastern portion but is so far only known to occur in Bertie and Currituck counties.

15. *P. nuttali* Harlan. Golden Mouse. Golden cinnamon above, yellowish white beneath passing gradually on the sides into the color of the back. Tail unicolor. Young similar to the adults in color. L. 6. T. $2\frac{1}{2}$. An arboreal species building its nest 6 to 12 feet high in reeds or bushes in lowland thickets. Probably common throughout most of the State, as it has been taken in Bertie, Wake, Halifax, Perquimans, and Buncombe counties.

GENUS ORYZOMYS, BAIRD (Marsh Rats).

16. *O. palustris* Harlan. Ricefield Rat. Dark brown above, whitish below, ears short, furry, tail about as long as head and body, hind feet large. L. $9\frac{1}{2}$. T. $4\frac{3}{4}$. A semi-aquatic species inhabiting cattail swamps and marshes from Florida to New Jersey. In this State it has only been taken in Wake county (Raleigh), where it is not uncommon in suitable situations.

GENUS NEOTOMA, SAY & ORD (Wood Rats.)

17. *N. pennsylvanica* Stone. Alleghany Cave Rat. Grayish above, white below. Tail sharply bicolor. L. $16\frac{1}{4}$. T. $7\frac{3}{8}$. Common in caves and rocky woods throughout the Alleghanies. Only known in this State from Roan Mt., Mitchell county.

(*N. floridiana* Ord. Wood Rat. Brownish gray above, the sides more yellowish, white below, tail furry, bicolor. L. 16. T. $7\frac{1}{2}$. I have had nests described to me by colored men, who said they had seen them many years ago in the eastern part of the State, which might have belonged to this species. So far as I know, however, it is not known to occur nearer here than southern Georgia.)

GENUS SYNAPTOMYS, BAIRD.

18. *S. cooperi* Baird. Cooper's Lemming. Color grizzled gray and yellowish brown above, thickly sprinkled with black; dirty white below. L. $4\frac{7}{8}$. T. $\frac{3}{4}$. Only known in this State from Roan Mt., Mitchell county, and Chapanoke, Perquimans county. Inhabits sphagnum bogs.

GENUS FIBER, CUVIER (Muskrats).

19. *F. zibethicus* L. Muskrat. Color brown, much suffused with yellowish and reddish (or black above and below, or black above and paler below than in the common form). L. 24. T. $10\frac{1}{2}$. Common along streams throughout the State.

The black form with pale belly is not uncommon at Raleigh, and we have also had it from Hyde county. The all black form we have only seen from Hyde county.

20. *F. macrodon*, Merriam. Dismal Swamp Muskrat. "Color very much darker and teeth very much larger, otherwise as in *F. zibethicus*" (Jordan's Manual) described from Dismal Swamp, Virginia, but undoubtedly has no respect for State lines.

GENUS *MICROTUS*, SCHRANK (Meadow Mice or Voles).

21. *M. pennsylvanicus pennsylvanicus* Ord. Meadow Mice. Upper parts dark brown, much sprinkled with black, under parts gray. L. $6\frac{3}{4}$. T. 2. Common at Raleigh and in Mitchell and Buncombe counties. The common mouse of wet meadows, but occurring sparingly on the uplands. Not known south of North Carolina, except in the mountains.

22. *M. pennsylvanicus nigrans* Rhoads. Albemarle Meadow Mouse. Above dark brownish slate black, dark brown on sides, under parts dark brown. L. 7. T. 2. Only known from Currituck, Currituck county, the type locality.

23. *M. pinetorum pinetorum* LeConte. Pine Mouse. Fur dense velvety and mole like, eyes and ears very small, claws on forefeet longest. Color above chestnut, ashy below, young slaty. L. 5. T. $\frac{7}{8}$. Common at Raleigh and in Bertie and Currituck counties, and probably throughout the State. This species digs burrows of its own or follows the mole runs under ground, feeding on such crops as peanuts, sweet potatoes and Irish potatoes without the damage being evident till the crop is dug.

24. *M. pinetorum scalopsoides* Aud & Bach. Northern Pine Mouse. Adults reddish brown, lighter than in *pinetorum*. One specimen from Magnetic City, Mitchell county, and two from Currituck referred to this form by Bailey (*N. A. Fauna*, No. 17, 1900).

GENUS *EVOTOMYS*, COUES.

25. *E. carolinensis* Merriam. Carolina Redbacked Mouse.

Ears large, projecting conspicuously above the fur, back dark chestnut fading insensibly into the brown of the sides. L. $5\frac{7}{8}$. T. $1\frac{3}{4}$. Probably found on the higher summits of the mountainous region of the State, but so far recorded only from Macon and Mitchell counties.

FAMILY CASTORIDAE (THE BEAVERS).

Large, clumsily built, aquatic rodents with four broad, rootless cheek teeth in each side of each jaw. Tail very broad and scaly, flattened from above, downward.

GENUS CASTOR, L.

26. *C. canadensis carolinensis* Rhoads. Carolinian Beaver. Scaly portion of tail less than twice as long as wide, fur relatively short and harsh. L. 35. In this State the beaver occurs sparingly on the Dan River in Stokes county (the type locality of the subspecies) and is also reported from Bertie county. A specimen taken some fifteen or twenty years ago at Weldon is in the State Museum at Raleigh. These localities are all on the Roanoke River or its tributaries. Mr. J. H. Armfield reports a few occurring in Beaver Swamp in the northern part of Guilford county and southern part of Rockingham, and Mr. K. E. Shore reports them from the Yadkin River, between Yadkin and Forsyth counties.

FAMILY SCIURIDAE (THE SQUIRRELS).

Upper front teeth two; upper cheek teeth four or five on each side; lower cheek teeth four on each side. A well developed bony process on skull above and behind eye socket (post-orbital process); tail round covered with long hairs which are usually so arranged as to form a broad flat brush. Four of the North American genera occur in the State.

- a. Sides with a densely furred membrane joining front and hind legs (Flying Squirrels).... GENUS SCIUROPTERUS.
- aa. Sides without membrane.

- b. Form stout and clumsy; tail less than half as long as body; skull nearly flat on top (Woodchucks).

GENUS ARCTOMYS.

- bb. Form slender and graceful; tail much more than half as long as body; top of skull distinctly rounded.

- c. Cheek pouches present; back striped (Chipmunks).

GENUS TAMIAS.

- cc. Cheek pouches absent; back not striped (Squirrels).

GENUS SCIURUS.

GENUS SCIURUS, L. (Squirrels).

27. *S. hudsonius loquax* Bangs. Southern Red Squirrel, Mountain Boomer. Back red, under parts white, edge of tail yellowish. L. $12\frac{1}{2}$. T. $5\frac{1}{8}$. (The length of tail does not include the distance the hairs project beyond the flesh but is the length of the tail vertebrae only. This is important to note in the case of the Squirrels and other mammals with hairy tails.) The Mountain Boomer is found throughout the mountains of the State from Cherokee to the Virginia line.

28. *S. carolinensis* Gmelin. Southern Gray Squirrel. Size medium, back dark yellowish rusty-gray. L. 18. T. 8. Common throughout the whole State.

29. *S. niger* L. Southern Fox Squirrel. Largest of the eastern Squirrels. Color very variable, gray, rusty or black, but the ears and nose are always white. Feet and hands very large, fur coarse and harsh. L. 25. T. 12. Said by Bangs to be wholly confined to the great pine forest of the South Atlantic and Gulf States. Only known in this State from Tarboro and Craven county. Specimens from the latter county are in the State Museum.

(*S. ludovicianus* Gray. Northern Fox Squirrel. Back mixed black and rusty, belly varying from pale rust color to rusty white; ears rusty (never white but the nose is sometimes white). L. 23. T. $10\frac{1}{2}$. Fox Squirrels are recorded from the neighborhood of Asheville by Mr. N. W. Fain, and from Cherokee county by Dr. Donald Wilson and may be this species or the preceding. Dr. Wilson sent me a skin without

the skull from his county which I sent to Mr. Outram Bangs for determination, and he wrote me as follows: "About the squirrel I am puzzled. If I had the skull I could be sure. It looks to me, however, like *neglectus* rather than *niger*. There is a great difference in size between them, and this skin seems small, but of course I cannot tell how old it is. The color is variable in both species, but as you say, the ears in your skin are not white enough. Although a very unsatisfactory identification, I think I should call it *Sciurus ludovicianus neglectus*. I should hate, however, to publish this as positive proof one way or the other, without seeing the skull."

GENUS TAMIAS, ILLIGER (Chipmunks).

30. *T. striatus* L. Chipmunk. Reddish brown, back with five black stripes and two whitish ones. L. 11. T. $4\frac{1}{2}$. The Chipmunk is found throughout the western half of the State extending as far east as the western edge of Raleigh township, in Wake county, and as far south as Cherokee in the mountains.

GENUS ARCTOMYS, SCHREBER (Woodchucks).

31. *A. monax* L. Woodchuck, Ground Hog. Grizzly gray, varied with chestnut, yellowish and blackish; under parts reddish. L. 18. T. $4\frac{1}{2}$. Common throughout the mountainous region of the State.

GENUS SCIUROPTERUS, F. CUVIER (Flying Squirrels).

32. *S. volans* L. Flying Squirrel. Back drab, somewhat shaded with russet, belly pure white to extreme base of hairs. L. 9. T. 4. Common throughout the whole State.

ORDER III. INSECTIVORA.

Canine teeth present, but usually not conspicuously developed; cheek teeth formed for chopping; toes provided with

claws; brain small. (Our species are all small, under 8 inches in length, eyes and ears small or rudimentary, fur more or less molelike.)

Two families occur in North America and another in the West Indies, while no members of this group are known from South America except the extreme northwest corner only.

a. Forefeet highly modified for digging; external ear absent (Moles) FAMILY TALPIDAE.

aa. Forefeet not highly modified for digging; external ear present (Shrews) FAMILY SORICIDAE.

FAMILY TALPIDAE (THE MOLES).

Body thick and clumsy without distinct neck; eyes rudimentary or concealed; no external ear; front feet very large, the nearly circular palm held lengthwise; fur very soft and velvety.

a. Tip of muzzle with a fringe of fleshy projections; tail long; teeth 44. GENUS CONDYLURX.

aa. Tip of muzzle without a fringe of fleshy projections; tail short.

b. Teeth 36; tail slender and nearly naked. GENUS SCALOPS.

bb. Teeth 44; tail thick and very hairy.

GENUS PARASCALOPS.

GENUS CONDYLURA, ILLIGER.

33. *C. cristata* L. Starnosed Mole. Dusky brown, paler and grayer below; tail nearly as long as head and body. L. $6\frac{3}{4}$. T. $2\frac{7}{8}$. Known only in this State from Mitchell county, where it was taken at Magnetic City by the collectors of the Biological Survey of the United States Department of Agriculture in 1892 or 1893, and from Buncombe county, where a single specimen was taken by Mrs. J. S. Cairns, at Weaver-ville, February 6, 1896. It is said to inhabit wet places.

GENUS PARASCALOPS, TRUE.

34. *P. breweri* Bachm. Brewer's Mole. Dark lead gray,

seldom, if ever, tinged with rusty. Tail dark. L. 5 13-16. T. 1 3-16. Like the preceding, a northern species extending its range southward in the mountains. Said to inhabit dry soil. Known only in this State by the numerous specimens taken by the collectors of the United States Biological Survey in 1892 and 1893 at Magnetic City, in Mitchell county.

GENUS SCALOPS, ILLIGER.

35. *S. aquaticus* L. Common Mole. Light glossy slate brown, tinged with rusty; tail whitish. L. 6¾. T. 1 1-16. The Common Mole is abundant throughout the State.

FAMILY SORICIDAE (THE SHREWS).

Body usually slender and mouse like with a distinct neck, eyes well developed but very small, a distinct external ear, front feet small, not mole like. Shrews are small animals, something like mice, but with pointed snouts and small eyes, the Mole Shrews of the genus *Blarina* have, however, a casual resemblance to little moles, except in the forefeet. Two genera occur in North Carolina.

a. Ears completely hidden by the fur, tail short.

GENUS BLARINA.

aa. Ears distinctly visible, tail long.

GENUS SOREX.

GENUS BLARINA GRAY.

a. *Teeth 32, total length 4 inches or over (subgenus Blarina).*

36. *B. brevicauda* Say. Mole Shrew. Color sooty slate brown above, more ashy below. L. 4¾. T. 1. Found throughout the mountains of the State from Cherokee to the Virginia line.

37. *B. carolinensis* Bachm. Carolina Shrew. Very similar to the preceding, but smaller and more slender, being only about 4 inches in total length. Occurs probably throughout the State except in the mountains, but has only been taken in Wake (Raleigh, Apex) and Perquimans counties (Chapanoke).

38. *B. telmalestes* Merr. Dismal Swamp Mole Shrew. About same size as *brevicauda*, but more plumbeous in color, and with a narrower skull. Taken by Dr. Merriam at Dismal Swamp, Virginia, and by Mr. R. T. Young, at Chapanoke, Perquimans county, and Currituck, Currituck county. The relationship of this and the two preceding forms to one another does not seem clear to me and hence I list them as full species "without prejudice."

aa. Teeth 30, in our species length about 3 inches.

39. *B. parva* Say. Little Mole Shrew. Color brownish above, ashy below. L. 3. T. 9-16. Its range in the State is probably about that of *B. carolinensis*, but it is at present only recorded from Wake and Bertie counties.

GENUS SOREX, L.

(a. Total length over $5\frac{1}{2}$ inches; hind feet conspicuously fringed (subgenus *Neosorex*). *S. albibarbis* Cope. Eastern Marsh Shrew. Upper parts blackish slate with a slight hoary cast; chin and throat grayish white, rest lower parts of dusky. L. $6\frac{1}{8}$. T. $2\frac{3}{4}$. The Marsh Shrew inhabits marshes and the borders of streams, south in the mountains to Pennsylvania and probably further.)

aa. Total length under 5 inches, hind feet not fringed (subgenus *Sorex*).

40. *S. fumeus* Miller. Smoky Shrew. Smoky slate color, slightly paler below. L. $4\frac{1}{8}$. T. $1\frac{3}{4}$.

41. *S. personatus* Geoff St. Hil. Masked Shrew. Upper parts dark brown, under parts whitish gray. L. $4\frac{1}{8}$. T. 1 9-16. This and the preceding have both been taken by the collectors of the United States Biological Survey on Roan Mt., Mitchell county, in 1892.

42. *S. longirostris* Bach. Southern Shrew. Smallest of the eastern shrews. Chestnut brown above, ashy tinged with drab below. L. $3\frac{3}{8}$. T. $1\frac{1}{4}$. Rare at Raleigh and one specimen known from Bertie county. The limits of the range

of this species are unknown, the above specimens being the only ones known to have been taken anywhere, since the species was described by Bachman from specimens taken in the swamps of the Santee River, South Carolina.

43. *S. fisheri*, Merr. Dismal Swamp Shrew. Similar to the preceding, but larger and coloration duller. L. $4\frac{1}{8}$. T. $1\frac{1}{2}$. This and the preceding have the third unicuspid tooth decidedly smaller than the fourth, whereas in *S. fumeus* and *S. personatus* the reverse is the case. Described by Dr. Merriam from Dismal Swamp, Virginia, and taken by Mr. R. T. Young at Chapanoke, Perquimans county.

ORDER IV. CHEIROPTERA. (BATS.)

Forelimbs greatly developed, the elongated fingers supporting a membrane by means of which true flight is performed.

- a. Tail included in the flying membrane nearly or quite to tip, nose without leaf-like fleshy growths.

FAMILY VESPERTILIONIDAE.

- aa. Tail in our species free from the membrane for its apical half.

FAMILY EMBALLONURIDAE.

(One species of the Emballonuridae, *Nyctinomus cynocephalus* Lec. The Florida House Bat, a small brown bat with tail projecting for about half its length beyond the membrane and with naked wings is common in Florida and the Gulf States and may possibly occasionally straggle as far north as this State.)

FAMILY VESPERTILIONDAE. (The Typical Bats.)

- a. Nostrils simple, at tip of snout; ears moderate; forehead not grooved.
b. Upper front teeth four, membrane between legs not completely furred above.

c. Fur blackish, frosted with white.

GENUS LASIONYCTERIS.

cc. Fur not blackish, not frosted with white.

d. Total length over four inches, teeth 32.

GENUS VESPERTILIO.

dd. Total length under four inches.

e. Color dull brown; ears rather long; teeth 38.

GENUS MYOTIS.

ee. Color light yellowish brown, teeth 34.

GENUS PIPISTRELLUS.

bb. Upper front teeth two.

f. Membrane between hind legs completely furred above,
ears short and round.

GENUS LASIURUS.

ff. Membrane between hind legs not furred above.

GENUS NYCTICEIUS.

aa. Nostril margined behind by grooves; cheeks with large
excrescences; ears very large, an inch high.

GENUS CORINORHINUS.

GENUS LASIURUS, GRAY.

44. *L. cinereus* Beauv. Hoary Bat. General color a mixture of light yellowish brown, deep umber brown, and white. L. $5\frac{1}{2}$. T. 2. Spread of wing 14. Has been taken by Cairns in Buncombe county, and the Smithwicks in Bertie county and Coues records it as occasional in summer at Fort Macon.

45. *L. borealis* Muller. Red Bat. General color varying from rufus red to yellowish gray, a white spot at shoulder, sometimes connected with its fellow by a white chest band. L. $4\frac{1}{4}$. T. 2. Spread 12. Common in Wake, Bertie, Buncombe, and at Fort Macon, also at Magnetic City, and on Roan Mt., and probably throughout the State.

GENUS NYCTICEIUS, RAF.

46. *N. humeralis* Raf. Twilight Bat. Dull umber brown

above, paler below. Common in Bertie, Wake and Buncombe, and probably throughout the State. L. $3\frac{1}{2}$. Spread 9.

GENUS MYOTIS, KAUP.

47. *M. subulatus* Say. Say's Bat. Dull brown, slightly paler and more yellowish below. Ear when laid forward reaching considerably beyond nose. L. $3\frac{3}{8}$. Spread 9. A single specimen taken at Raleigh September 13, 1902, is referred by me to this species as it agrees with the foregoing characters.

48. *M. lucifugus* Lec. Little Brown Bat. Ear when laid forward barely reaching nostril, size and color as in *M. subulatus*. Mr. G. S. Miller, Jr., mentions a specimen from Mitchell county, and has identified a specimen from Buncombe county, kindly loaned me by Mr. W. E. Snyder, as this species, and Dr. Witmer Stone refers to it a specimen from Bertie county. Besides these, I have seen 6 from Buncombe, 2 from Bertie county, and 2 from Raleigh, which were either this or the preceding, but at the time we had them, the two species were confused, and I have been unable to locate the specimens and have them correctly placed.

GENUS LASIONYCTERIS, PETERS.

49. *L. noctivagans* Lec. Silver Black Bat. Blackish, frosted with white, membrane between hind legs furred to about the middle above. L. 4. Spread of wing 12. This bat apparently occurs all over the State, but does not seem to be common in any locality. Six specimens are recorded from Bertie county, a dozen or more from Wake, one from Buncombe, and one from Mitchell.

GENUS PIPISTRELLUS, KAUP.

50. *P. subflavus* F. Cuvier. Georgia Bat. General color light yellowish brown. L. $3\frac{3}{8}$. Spread 9. This is the smallest of our bats and is common in Bertie, Buncombe and Wake, and probably throughout the State.

GENUS VESPERTILIO, L.

51. *V. fuscus* Beauv. Big Brown Bat. Brown, paler below. $4\frac{3}{8}$. Spread 12. This species is known from Bertie, Wake and Buncombe, but is not common in either county.

GENUS CORINORHINUS, H. ALLEN.

52. *C. macrotis* Lec. Big Eared Bat. Blackish, fur soft and long. L. $3\frac{1}{2}$. Spread 11. One taken by Cairns at Weaverville, Buncombe county, April 7, 1895, and three by the Smithwicks in Bertie county, February 1, 1893, and October 24, 1894, (two specimens) are the only records we have of this southern species. (Since the above was written the State Museum has received a specimen from Goldsboro.)

ORDER V. UNGULATA.

(THE HOOFED ANIMALS.)

Herbivorous mammals provided with one to four enlarged and thickened hoofs on each foot. The order contains mainly large species and includes such domestic animals as the horse, cow, hog, sheep, goat, etc.

Only one of the two groups of Ungulata, the Artiodactyla or even toed Ungulates, is represented in our fauna, and only two families of that.

Families of Ungulata now or formerly occurring in the State:

- a. Horns solid, usually branching, present in our species only in the male (The Deer). FAMILY CERVIDAE.
- aa. Horns permanent, hollow, each enclosing a bony core or process of the skull (The Cattle). FAMILY BOVIDAE.

FAMILY CERVIDAE (THE DEER).

Horns solid, shed every year; wanting in the female except

in the Reindeer. Only one species occurs in the State, but another doubtless did in earlier days.

a. Horns large, curved mostly backward, the tines all directed forwards, size large. GENUS CERVUS.

aa. Horns small, curved forward, the tines all directed upwards, size smaller. GENUS ODOCOILEUS.

GENUS CERVUS, L.

(*C. canadensis* Erxl. Eastern Wapiti, American Elk. Reddish brown, paler in winter; height at shoulders five feet; horns five feet long. Now extinct in the United States, but probably occurred in the western part of the State 150 years ago.)

GENUS ODOCOILEUS, RAF.

53. *O. virginianus* Bodd. Virginia Deer. Color in summer reddish, grayer in winter, under parts white. Not uncommon in the eastern section of the State and in the mountains, but rare or absent in the more thickly settled portions of the center.

FAMILY BOVIDAE. (THE CATTLE AND ANTELOPES.)

Only one genus, Bison, ever occurred east of the Mississippi, the cow, goat and sheep belong to this family.

GENUS BISON, H. SMITH.

(*B. bison* L. American Bison, Buffalo. The Buffalo was no doubt found in the western part of the State in early days.)

ORDER VI. FERAEE.

(THE CARNIVORA OR FLESH EATERS.)

Canine teeth well developed, cheek teeth formed for cutting,

front teeth small in a row between the canines. Toes provided with claws. Brain large, well developed.

- a. Limbs modified for swimming and useless for walking, hind feet not capable of being turned forward (The True Seals). FAMILY PHOCIDAE.

- aa. Limbs fitted for walking.

- b. Hind feet with 4 toes.

- c. Claws capable of being withdrawn into a sheath, muzzle broad and short, teeth not more than 30 (The Cats). FAMILY FELIDAE.

- cc. Claws blunt, not retractile, teeth 42 (Dogs, Wolves and Foxes). FAMILY CANIDAE.

- bb. Hind feet with five toes.

- d. Entire sole applied to the ground in walking.

- e. Size large, tail rudimentary (The Bears).

FAMILY URSIDAE.

- ee. Size medium, tail well developed (Raccoons).

FAMILY PROCYONIDAE.

- dd. Entire sole not applied to the ground in walking (Weasels, Minks, Otters, Skunks, etc.).

FAMILY MUSTELIDAE.

FAMILY PHOCIDAE. (THE SEALS.)

Only one genus and species occur on the coast.

GENUS PHOCA, L.

54. *P. vitulina* L. Harbor Seal. Grayish or brownish. L. five feet, female smaller. Occasional on our coast. A female in the State Museum from Craven county.

FAMILY PROCYONIDAE.

Plantigrade carnivora of small size with comparatively slender body and well developed tail. Teeth 40. Only one genus and species occur in the eastern United States.

GENUS PROCYON, STORR.

55. *P. lotor* L. Raccoon, Coon. Grayish, hairs black tipped with black rings, a black cheek patch. L. 33. T. 10½. The Raccoon is still found throughout the State, but is quite rare in the more thickly settled districts.

FAMILY URSIDAE (THE BEARS).

Plantigrade carnivora of large size, with rudimentary tail. Only one genus and species is known from the State.

GENUS URSUS, L.

56. *U. americanus* Pallas. Common American Bear, Hog Bear. Color blackish or brownish, variable. Still not uncommon in the swamps of the eastern and mountains of the western parts of the State, but not now found in the central portion.

FAMILY MUSTELIDAE (THE WEASELS).

Carnivora with the feet either plantigrade or digitigrade, the toes five on all four feet. Most species are provided with glands near the anus which secrete a bad smelling liquid. Teeth 32 to 38. Our species are usually of small or medium size.

a. Toes conspicuously webbed, snout short, high and blunt, teeth 36 (Otters). GENUS LUTRA.

aa. Toes not much webbed, snout longer, teeth 34.

b. Tail closely furred, claws short (Minks and Weasels).

GENUS PUTORIUS.

bb. Tail bushy, claws long (Skunks).

c. Form stout and heavy.

GENUS MEPHITIS.

cc. Form slender.

GENUS SPILOGALE.

GENUS LUTRA, BRISSON.

57. *L. hudsonica* Desm. American Otter. L. 3½ feet. T. 16 inches. Color liver brown. Our form is *L. h. lataxina*

(F. Cuvier), with colors lighter than in the Northern Otter. The Otter is found throughout the State, but is apparently rarest in the mountains and most plentiful in the east.

GENUS PUTORIUS, CUVIER.

58. *P. vison lutrocephalus* Harlan. Carolina Mink. Color dark chestnut brown. L. 27. T. $8\frac{1}{4}$. The Mink is found commonly throughout the State, it being a semi-aquatic animal living mainly along watercourses.

59. *P. novboracensis notius* Bangs. Southern Weasel. Brown above, yellowish white below, tail brown, black for posterior half. L. 16. T. $5\frac{1}{2}$, the female much smaller, L. $12\frac{3}{4}$, T. $4\frac{1}{4}$. Rare in Wake (only two specimens seen in twenty years) and in Bertie, but rather common in Buncombe and Mitchell counties, and probably in the mountains generally. No Weasels are known in the eastern United States from south of Raleigh until we reach Florida.

GENUS MEPHITIS, CUVIER.

60. *M. elongata* Bangs. Large Southern Skunk. Polecat. Color black, a patch on the back of the head and two stripes extending back from it white. These stripes may be so greatly enlarged that the animal is nearly all white, or so greatly reduced that it is nearly all black. Tail very bushy with a white tip, the white on tail as variable in amount as that on body. L. 24. T. 9. Occurs only in the southern half of the State from the coast to the mountains. Very rare in Wake county, and not found in Bertie, Forsyth, Guilford, or other counties in the northern half of the State. The secretions of the anal glands (not urine, as is commonly supposed,) are so abundant and offensive in all skunks as to be the animal's chief weapon of offense.

GENUS SPILOGALE, GRAY.

61. *S. ringens* Merr. Little Striped Skunk. About the size and shape of a mink, color black with four narrow,

parallel, white stripes down the back, these breaking up on the rump into spots and transverse bars. Tail black with long, white pencil at tip. L. $18\frac{1}{2}$. T. $7\frac{1}{2}$. The Little Striped Skunk is found throughout the mountains where it seems to be commoner than the large skunk.

FAMILY CANIDAE (THE DOGS).

Carnivora that walk on the toes only, never on the sole of the foot; claws blunt; hind toes 4; teeth 42 in our species.

- a. Upper front teeth distinctly lobed, pupil of eye circular (Dogs and Wolves). GENUS CANIS.
- aa. Upper front teeth not lobed, pupil of eye elongate not circular.
 - b. Tail without mane of stiff hairs, and with abundant soft under fur (Red Foxes). GENUS VULPES.
 - bb. Tail with a concealed mane of stiff hairs and without soft fur (Gray Foxes). GENUS UROCYON.

GENUS CANIS, L.

62. *C. occidentalis* Rich. American Wolf. Back brownish or blackish mixed with tawny, belly light tawny or dirty whitish. Total length nearly five feet. Found sparingly throughout the mountains. Dr. Donald Wilson reports it from Graham county, Mr. R. W. Collett says it is growing very scarce in Cherokee, Mr. Fain says there are very few in Buncombe. Mr. H. H. Brimley, Curator of the State Museum, informs me it has been taken in recent years in Yancey, Caldwell and Watauga. Dr. Merriam states that in the year of one of his visits to Roan Mt. a den of wolves was discovered there and the young captured alive (in 1887 or 1892).

GENUS VULPES, RICHARDSON.

63. *V. fulvus* Desm. Red Fox. Reddish, feet and ears blackish, tip of tail white. L. 40. The commoner fox in the mountains and thence eastward along the northern border of

the State to Edgecombe (Foxhall). Not found in Bertie (Smithwick), Wake (Brimley), nor Forsyth (Shore).

GENUS UROCYON, BAIRD.

64. *U. cinereo-argenteus* Muller. Gray Fox. Back a coarse grizzle of blackish and white, belly and region about ears tawny. A black line along back of tail. L. 36. The Gray Fox is the common fox of the State except in the mountains where it is less common.

FAMILY FELIDAE (THE CATS).

Carnivora with short round head and retractile claws. Heel never applied to the ground in walking. Teeth 28 or 30.

a. Tail long, teeth 30, ears not tufted. GENUS FELIS.

aa. Tail short, teeth 28, ears tufted. GENUS LYNX.

GENUS FELIS, L.

65. *F. cougar* Kerr. American Panther, Puma. Yellowish brown above, middle line of back darker, under parts whitish. L. 8½ feet. T. 3 feet. A specimen killed near Rose Bay, Hyde, county, some years before the war between the States, according to Mr. Walton E. Stone, is the only authentic record from the State.

GENUS LYNX, KERR.

66. *L. rufus* Gueld. Wild Cat, Bay Lynx. Back yellowish gray tinged with rufous, much spotted and streaked with black, belly whitish spotted with black, a brownish collar on throat. L. 3 feet. T. 7 inches. Found in the wilder parts of the eastern and western portions of the State. Large specimens of this species are frequently called catamounts and supposed to be a different species, but in every case where the State Museum has endeavored to secure a "catamount," it has always proved to be this species and not the Canada Lynx, which does not occur in the State.

LIST OF PAPERS RELATING MORE OR LESS TO NORTH CAROLINA
MAMMALS AND CONSULTED BY THE AUTHOR:

- Allen, J. A., "Species of the Genus *Reithrodontomys*," Bull. A. M. N. H., Vol. XII., 1895, pp. 107 *et seq.* (Mentions *R. lecontei* from Raleigh, North Carolina, but gives its distribution erroneously, as "coast region of South Carolina and Georgia".)
- Allen, J. A., "Revision of the Chickarees," Bull. Am. Mus. Nat. Hist., Vol. X., 1898, Article XIV. (Mentions *Sciurus hudsonius loquax* from North Carolina.)
- Allen, J. A., "Five New North American Mammals," Bull. A. M. N. H., Vol. XII., 1899, page 13. (Mentions *Lepus floridanus mallurus* from Raleigh)
- Bangs, O., "Three New Weasels From North America," Proc. New Eng. Zool. Club, Vol. I., pp. 53-57, June 9, 1899. (Describes as new *Putoricus noveboracensis notius* from Weaverville and Raleigh, North Carolina.)
- Bangs, O., "Notes on North American Mammals," Proc. Boston Soc. Nat. Hist. Vol. XXVI., July 31, 1895.
- Bangs, O., "The Cotton Mouse (*Peromyscus gossypinus*)," Proc. Biol. Soc. Wash. Vol. X., pp. 119-125, Nov. 5, 1896. (Records specimens from Bertie county, North Carolina.)
- Bangs, O., "A New Race of the Chickaree," Proc. New Eng. Zool. Club, March 31, 1899, Vol. I., pp. 27-29. (Contains references to the Red Squirrels or Chickarees, of Roan Mt., North Carolina.)
- Bangs, O., "The Skunks of the Genus *Mephitis* of Eastern North America," Proc. Biol. Soc. Wash. Vol. X., pp. 139-144, Dec. 28, 1896. (Mentions the absence of skunks from parts of North Carolina.)
- Bangs, O., "The Land Mammals of Peninsular Florida and the Coast Region of Georgia," Proc. Bost. Soc. Nat. Hist., Vol. 28, pp. 151-235, March, 1898. (Mentions a number of North Carolina mammals.)
- Bangs, O., "A New Race of the Little Harvest Mouse From

- West Virginia", Proc. Biol. Soc. Wash., Vol. XII., pp. 167-168, August 10, 1898. (This form may occur in North Carolina.)
- Bangs, O., "Notes on the Synonymy of the North American Mink With Description of a New Subspecies", Proc. Bost. Soc. Nat. Hist., Vol. 27, pp. 1-6, March, 1896. (Contains references to Minks from North Carolina.)
- Bangs, O., "The Geographical Distribution of the Eastern Races of the Cottontail (*Lepus sylvaticus* Bach.) With Description of a New Subspecies", Proc. Soc. Nat. Hist., Vol. 26, pp. 404-416. (Mentions specimens from North Carolina.)
- Bangs, O., "A Review of the Squirrels of Eastern North America", Proc. Biol. Soc. Wash., Vol. X., pp. 145-167, Dec. 28, 1896. (Contains records of *Sciurus niger*, *S. hudsonius*, and *S. carolinensis* from North Carolina.)
- Bangs, O., "The Eastern Races of the American Varying Hare, With Description of a Subspecies from Nova Scotia", Proc. Biol. Soc. Wash., Vol. XII., pp. 77-82, March 24, 1898. (Mentions *Lepus americanus virginianus* as occurring as far south as White Sulphur Springs, West Virginia.)
- Bailey, V., "Revision of the American Voles of the Genus *Microtus*", N. Am. Fauna, No. 17, 1900. (Gives North Carolina records of *M. pinetorum*, *M. p. scalopsoides*, *M. pennsylvanicus*, *M. penn. nigrans*.)
- Batchelder, C. F., "Some Unrecognized Mice of the Genus *Zapus*", Proc. New Eng. Zool. Club, Vol. I., pp. 3-7, February 8, 1899. (Mentions *Z. hudsonius americanus* from Raleigh, North Carolina.)
- Brimley, C. S., "List of the Mammals of Raleigh, North Carolina", American Naturalist, May, 1897.
- Brimley, C. S., "An Incomplete List of the Mammals of Bertie county, North Carolina", American Naturalist, March, 1897.
- Coues, Elliott, "Notes on the Natural History of Fort Macon,

- North Carolina", Proc. Acad. Nat. Science, Philadelphia, May 2, 1871, pp. 1-49.
- Elliott, D. G., "A List of Mammals Obtained by Thaddeus Surber in North Carolina, South Carolina, Georgia, and Florida", Field Columbian Mus. Publ. 58, June, 1901.
- Howell, A. H., "Revision of the Skunks of the Genus *Chincha*" (*Mephitis*), N. A. Fauna, No. 20, 1901. (Mentions *Chincha clongata* from North Carolina.)
- Merriam, C. Hart, "Remarks on the Fauna of the Great Smoky Mountains, With Description of a New Species of Redbacked Mouse (*Evotomys carolinensis*)", Am. Journal of Science, Vol. XXXVI., December, 1888, pp. 458-460. (Applies wholly to North Carolina.)
- Merriam, C. Hart, "Description of Twenty-Six New Species of North American Mammals", N. A. Fauna, No. 4, 1890. (Mentions *Spilogale ringens* from Cherokee, North Carolina.)
- Merriam, C. Hart, "Synopsis of the Weasels of North America", N. A. Fauna, No. 11, 1896. (Mentions *P. noveboracensis* occurring in North Carolina.)
- Merriam, C. Hart, "The Occurrence of Cooper's Lemming Mouse in the Atlantic States", Proc. Biol. Soc. Wash., Vol. VII., pp. 175-177, December 22, 1891. (Mentions specimens from Roan Mt., North Carolina.)
- Merriam, C. Hart, "Description of a New Subspecies of Chipmunk", Am. Naturalist, Vol. XX., No. 2, February, 1896. (Mentions a specimen from Jackson county, North Carolina.)
- Merriam, C. Hart, "Revision of the Shrews of the Genera *Blarina* and *Notiosorex*", N. A. Fauna, No. 10, 1895. (Mentions *B. brevicauda*, *B. carolinensis*, and *B. parva* from North Carolina.)
- Merriam, C. Hart, "Synopsis of the American Shrews of the Genus *Sorex*", N. A. Fauna, No. 10, 1895. (Mentions *Sorex fumeus*, *S. personatus*, and *S. longirostris* from North Carolina.)

- Miller, G. S., J., "The Longtailed Shrews of the Eastern United States," N. A. F., No. 10, 1895. (Mentions *S. fumeus*, *S. personatus*, and *S. longirostris* from North Carolina.)
- Miller, G. S., Jr., "Key to the Land Mammals of Northeastern North America," Bull. N. Y. State Museum, 1900. (Mentions a number of mammals from North Carolina.)
- Miller, G. S., Jr., "Revision of the North American Bats of the Family Vespertilionidae," N. A. Fauna, No. 13, 1897. (Contains several North Carolina records.)
- Preble, E. A., "Revision of the Jumping Mice of the Genus *Zapus*," N. A. Fauna, No. 15, 1899. (Mentions *Z. hudsonius*, *Z. h. americanus*, and describes as new *Z. insignis roanensis* from North Carolina.)
- Rhoads, S. N., and Young, R. T., "Notes on a Collection of Mammals From Northeastern North Carolina," Proc. Acad. Nat. Sci., Philadelphia, 1897, pp. 303-312.
- Rhoads, S. N., "The Marsh or Ricefield Mice of the Eastern United States," American Naturalist, Vol. XXXVI., August, 1902. (Mentions *Oryzomys palustris* from Bertie county, North Carolina, which is an error, as the specimens actually came from Raleigh, Wake county.)
- Rhoads, S. N., "Contributions to the Zoology of Tennessee, No. 3, Mammals," Proc. Acad. Nat. Sci., Philadelphia, 1896, pp. 175-205. (Contains records of a number of species of mammals from Roan Mt., North Carolina.)
- Rhoads, S. N., "Contributions to a Review of the North American Beavers, Otters and Fishers," Trans. Am. Philos. Soc. N. S., XIX., pp. 417-439. (Describes *Castor c. carolinensis* from North Carolina and refers North Carolina Otters to *L. h. lataxina*.)
- True, F. W., "A Revision of the American Moles," Proc. U. S. Nat. Mus., Vol. XIX., pp. 1-112, 1896. (Contains North Carolina records of *Parascalops breweri*, *Condylura cristata* and *Scalops aquaticus*.)

THE METHOXYL GROUP IN CERTAIN LIGNOCELLULOSES.

ALVIN S. WHEELER.

Extended study of lignified tissue has led to the belief that it is essentially a chemical compound and the term lignocellulose is applied to it. The molecule is a very complex one and among the characteristic features of it is the constant proportion of methoxyl, OCH_3 . Benedikt and Bamberger* first brought this fact into prominence. The proportion of methoxyl, calculated to methyl, is approximately two and one half per cent. I have extended the work, making determinations in woods mostly native to this country. The Tree of Heaven, China Tree and Paulownia originated in Eastern Asia but are now found wild in this country. The Crab Wood and Wild Lime are native to the Bahama Islands and the West Indies and the samples were obtained from Dr. W. C. Coker.

The determinations were made according to the method of Zeisel. In most cases the wood was taken from small stems. It was cut into small chips, after removal of the bark and dried to constant weight in a steam oven. The values obtained correspond to those of Benedikt and Bamberger. The results are as follows:

Persimmon,	Diospyros Virginiana, L.	1.95
Umbrella Tree,	Magnolia tripetala, L.	2.57
Sassafras,	Sassafras Sassafras (L) Kant	2.44
Chinquapin,	Castanea pumila, (L) Mill	2.16
Buttonwood,	Platanus occidentalis, L	2.23
Witch Hazel,	Hamamelis Virginiana, L	2.67
Pig Nut Hickory,	Hicoria glabra, (Mill) Britton	2.32

*Monatsh. of Chem. II., 260-267.

Sweet Gum,	Liquidambar Styraciflua, L	2.24
Dogwood,	Cornus florida, L	2.37
Honey Locust,	Gleditsia triacanthos, L	2.47
Tree of Heaven,	Ailanthus glandulosa, Desf.	2.52
China Tree,	Melia Azederach, L	2.35
Paulownia,	Paulownia tomentosa, (Thunb)	2.40
Crab Wood,	Gymanthes lucida,	2.95
Wild Lime,	Fagara flava,	2.19

The average is 2.39 per cent. I wish to thank Mr. Preston Irwin for assistance in making the determinations.

Chapel Hill, N. C.

THE SPONGES OF THE "ALBATROSS" 1891 EXPEDITION.

Memoirs of the Museum of Comparative Zoology at Harvard College, Vol. XXX., No. 1. *Reports on an Exploration off the West Coasts of Mexico, Central and South America, and off the Galapagos Islands*, in charge of Alexander Agassiz, by the U. S. Fish Commission Steamer "Albatross," during 1891, Lieut. Commander Z. L. Tanner, U. S. N., commanding. XXX. *The Sponges*, by H. V. Wilson. Cambridge, U. S. A., 1904. Pp. 164, with 26 plates.

The following synopsis of results is abstracted from the introduction to the above report.

The collection of sponges with which the following report deals has been found to include forty-seven species and subspecies. Of these, twenty-six, representing thirteen genera, fall into the Hexactinellida, seven, representing three genera, fall in the Tetractinellida, and fourteen, representing nine genera, fall in the Monaxonida. No calcareous or horny sponges and no Lithistids were taken. As was to have been expected, since the expedition was made in unexplored waters, a very large percentage of the forms (thirty-three species and subspecies) prove new to science.

LIST OF THE SPECIES TAKEN.

Hyalonema ovuliferum F. E. Sch.

" *pedunculatum*, sp. nov.

" *bianchoratum*, sp. nov.

" *pateriferum*, sp. nov.

" sp. div.

Euplectella, sp.

Regadrella, sp.

" *delicata*, sp. nov.

Caulophacus schulzei, sp. nov.

“ sp.

Bathydorus levis spinosus, subsp. nov.

Staurocalyptus sp.

Farrea occa claviformis, subsp. nov.

“ *mexicana*, sp. nov.

“ sp.

Eurete erectum tubuliferum, subsp. nov.

“ “ *mucronatum*, subsp. nov.

“ “ *gracile*, subsp. nov.

“ sp.

Aphrocallistes vastus F. E. Sch.

Chonelasma calyx F. E. Sch.

Bathyxiphus sp.

Hexactinella labyrinthica, sp. nov.

“ *ventilabrum* Carter.

“ *tubulosa* E. E. Sch.

Sclerothamnopsis compressa, gen. et, sp. nov.

Thenea fenestrata (O. Schmidt) Sollas.

“ *echinata*, sp. nov.

“ *lamelliformis*, sp. nov.

“ *pyriformis*, sp. nov.

Poecillastra tricornis, sp. nov.

“ *cribraria*, sp. nov.

Penares foliaformis, sp. nov.

Polymastia maeandria, sp. nov.

Petrosia variabilis crassa, subsp. nov.

“ *similis densissima*, subsp. nov.

Pachychalina acapuclensis, sp. nov.

Oceanapia bacillifera, sp. nov.

Gellius perforatus, sp. nov.

Tylodesma alba., sp. nov.

“ *vestibularis*, sp. nov.

Iophon chilifer ostia-magna, subsp. nov.

“ *lamella*, sp. nov.

“ *lamella indivisus*, subsp. nov.

Iophon indentatus, sp. nov.

Phakellia lamelligera, sp. nov.

Auletta dendrophora, sp. nov.

In addition to the discovery of new forms, some results of general biological interest have accrued from the study of the collection, and are discussed or stated under the respective species concerned. For convenience of reference the more important of these facts may be here classified.

Remarkable forms. *Hyalonema pedunculatum* is noteworthy for the peculiar pedunculate form of body; *Sclerothamnopsis compressa* for the shrub-like habitus in which it resembles the hitherto unique *Sclerothamnus clausii* Marsh.; *Regadrella delicata* for the character of the sieve-plate region, which may be construed as representing a simpler (although not necessarily a more primitive) phylogenetic condition than the otherwise closely similar *Regadrella phoenix* O. Schm.

Distribution and Habitat. *Thenea fenestrata* O. Schm., hitherto known only from the Atlantic and Caribbean Sea, is now recorded for the Pacific. Some of the Hexactinellids from great depths have been found to live clustering upon one another: *Caulophacus* attached to root spicules of *Hyalonema*; *Bathydorus* attached to root spicules of *Hyalonema* and to stalks of *Caulophacus* or similar sponge.

Morphology in general. Further evidence of a convincing character has been gained that the *Eurete* and *Farrea* colonies are derived ontogenetically from simple cup-like forms. —The close similarity between the main afferent and efferent canals and their apertures in *Poecillastra tricornis* is worthy of remark. —The observations of Sollas and of Dendy on the occurrence of a peculiar fenestrated membrane (Sollas's membrane) in the flagellated chambers of certain sponges have been confirmed for two tetractinellid genera, *Poecillastra* and *Penares*.

Pathological phenomena in general. In *Euplectella* skeletal septa of a reticular character have been found crossing the

cavity of the sponge.—In *Chonelasma* similar septa have been observed.—In *Hexactinella labyrinthica* skeletal masses of a reticular character, such as have been especially described by Weltner, occur. In some cases such masses form layers separating one part of the sponge from another.—Possibly all these phenomena are pathological and similar, in so far as they may indicate an effort of the sponge to shut off one one part (diseased?) of the body from the rest.

Morphology of spicules—variations and “pathological” conditions. In *Hyalonema pateriferum*, pathological amphidiscs such as have been observed by Marshall and Meyer and F. E. Schulze occur. In these spicules several additional rays of the hexact are developed.—Certain details in the structure of the discohexasters of *Caulophacus schulzei* suggest that a hexaster may arise from a hexact through the development of *lateral* branches on the hexact rays.—Another case is afforded by *Hexactinella labyrinthica* of what seems to be the degeneration of an uncinat into an oxydiact.—In scopulae present in *Sclerothamnopsis compressa*, the arrangement of the axial canals indicates that the spicule is equivalent to a branched diact, as Schulze has supposed.—Abundant transitional forms indicate that the protriaenes of *Thenca* are modified *dichotriaenes*.—In *Thenca pyriformis* a type of metastar is common which may be interpreted as transitional between spirasters and euasters.—In *Penares foliaformis* peculiar *dichotriaenes* are found which approach the shape of the lithistid phyllotriaene.—The occurrence of pathological branching oxeas is recorded for *Petrosia*.

Variation. The variability of sponges in regard to points of adult structure is universally recognized. O. Schmidt and Vosmaer, in particular, have laid stress on the phenomenon as bearing upon the problems of systematic classification. The observations recorded in this report will fall under the following heads:

1. *Variation in body-shape and general anatomy.*

Attention may be called to the difference in shape exhibited

by specimens of *Hyalonema pateriferum*, *Caulophacus schulzei*, *Thenca fenestrata*, *Petrosia variabilis crassa*.—In *Eurete* the spiral form of body beset with cup-like outgrowths varies towards a bilateral symmetry.—In *Tylodesma alba* massive and lamellate bodies occur, as parts of one continuous specimen.—In *Gellius perforatus* a uniform habit of growth may result in very different body shapes.—In *Thenca* individuals the number and size of pore areas vary; also the spicular fringe round the osculum.—In *Iophon lamella* the character of the surface varies in different parts of the same individual, owing to the divergence in character of the main efferent canals and their apertures, and to the varying amount of colenchyma round such canals.

2. *Variation in same individual in the skeletal framework, or the skeleton in general.*

In *Chonelasma calyx* the tuberculation of the beams of the dictyonal framework varies.—In *Hexactinella ventilabrum* there is considerable variation in the way in which the hexacts combine to form the dictyonal framework.—In *Thenca fenestrata* there is variation in the development of the spicular fringes round the pore areas.—In *Petrosia variabilis crassa* and in *Petrosia similis densissima* a skeletal reticulum remains undeveloped in spots.—In *Pachychalina acapulcensis* the skeletal framework in places is fairly regular, although in general irregular. In *Phakellia lamelligera* the skeletal lamellae vary in respect to branching.—In *Petrosia similis densissima* over some parts of the surface there are no projecting spicules, while over other parts such spicules are present in considerable number.—In *Gellius perforatus* there is considerable variation in the character of the spicular tufts which project from the surface.—In *Iophon lamella* there is variation in the number of spicules which combine to form the side of a skeletal mesh.

3. *Uncorrelated Variation in the megascleres of an individual*, i. e. variation apparently not correlated with the structural peculiarities of the body-locality.

As regards size of the spicules, there seems to be noticeable variation in all sponge species.—The shape of one of the macramphidiscs varies considerably in *Hyalonema bianchoratum*.—In *Caulophacus schulzei* the principal hexacts are occasionally tuberculated, and in the same species the tuberculation of the pentacts varies.—The character of the diact ends varies commonly, e. g. in *Bathydorus levis spinosus*.—In *Farrea mexicana* the pentacts vary in respect to tuberculation.—In *Eurele erectum* the character of the distal ray of the gastral pinules varies extensively.—In *Petrosia variabilis crassa* the oxea sometimes assumes the shape of a strongyle, or style.—In *Penares foliaformis* the triaenes vary considerably.—In *Pachychalina acapulcensis* the size of the oxea varies within wide limits.----In *Phakellia lamelligera* the oxeas and the two kinds of styles all vary considerably in shape.

4. *Uncorrelated variation in the microscleres of an individual.*

The microscleres as well as the megascleres very commonly vary in size and detailed shape, although in them, as in the megascleres, there is a size and pattern which are characteristic of the individual (species), i. e. to which the majority of the spicules of an individual conform.

Some striking cases of variation are afforded by the microoxyhexacts of *Hyalonema bianchoratum*, plesiasters and spirasters of *Thenea fenestrata*, sigmata of *Tylodesma alba*.

5. *Correlated variation in the spicules.*

In some cases the variation of spicules is obviously not ungoverned by the rest of the body, but is correlated with body-locality.

Thus while the pentacts in *Hexactinella labyrinthica* vary at large in respect to length of the several rays, the pentacts overlying the larger inhalant canals commonly have noticeably short proximal rays. Such a phenomenon would customarily be referred to as "adaptive."—The variation of dichotriaenes towards the protriaene type, round the pore areas of

Thenca, is another instance of the same phenomenon.—A complex instance of correlated variation is afforded by the dermal and gastral pinules of *Caulophacus schulzei*, which coat the opposite surfaces (pore and oscular) of the body. The two kinds of pinules vary in the same direction in different individuals, and thus the proportionate difference between them is preserved.

6. *Qualitative variation.*

Two sets of individuals living together in the same locality, and which are otherwise indistinguishable, differ conspicuously in respect to a single point. An instance is afforded by *Eurete erectum mucronatum*, which differs from *Eurete erectum tubuliferum* in having oxyhexasters instead of onychasters. Another instance is afforded by *Iophon lamella indivisus*, which differs from *Iophon lamella* only in the character of the bipocillus, which is not chelate.——In order not to confuse the facts with hypothesis, the two sets of individuals have in each case been separated as subspecies. It is idle to dogmatize or to speculate *in extenso* on the value, from the standpoint of heredity, of the point of difference. Whether this point is inheritable and thus marks off two races, or whether it merely marks off two sets of individuals which started out alike and the offspring of which are alike, and which owe their difference to the action on the individual of the environment, no one can say. The recording of the difference is the duty of the systematist, who, when he has done so, has pointed out an additional case suitable for the experimental study of heredity and environmental action.

7. *Variation towards other species or subspecies.*

A class of spicules in one subspecies may vary in considerable number towards a condition characteristic of a subspecies inhabiting a different locality. An instance is afforded by *Eurete erectum gracile*, in which the tuberculation of the gastral pentacts and hexacts is sometimes very similar to that found in the other subspecies of *Eurete erectum*.

Or a form of spicule characteristic of one species may occur

infrequently in a related species. For instance, in *Caulophacus schulzei* the pinuli occasionally have the shape characteristic of *C. latus* and *C. elegans*. A striking case is afforded by *Farrea occa claviformis*, in which a few gastral clavulae were found closely similar to the peculiar clavulae of *Farrea convolvulus*.

8. *Constancy of character in spicules.*

It often happens that while in a single individual the *size* of a particular spicule may vary within wide limits, the *character* remains fairly constant—e. g. pinuli of *Hyalonema bianchoratum*.—The character of a spicule even in minute details may apparently become fixed for the species. Thus in a specimen of *Hyalonema ovuliferum* the rays of the microoxyhexacts have the same sudden terminal curving exhibited by the corresponding spicules of Schulze's type specimen, although the two sponges were taken 49° of latitude apart. —A form of spicule which in some sponges varies greatly in size, in other species varies but little. Thus in *Gellius perforatus* the sigmata vary only slightly, whereas in *Tylodesma alba* they vary greatly.

I do not undertake a comparative consideration of the geographical distribution of the forms making up the collection. Such a consideration would demand a knowledge of the actual systematic value to be attached to many *species* recorded in the literature of sponges. And such a knowledge is not to be had at present. In modern sponge literature, e. g. in the two great monographs of Schulze and Sollas (Schulze, 1887; Sollas 1888), the species conceived are, as it seems to me, what H. M. Bernard contends for in his interesting recent discussions (Proc. Cambridge Phil. Soc. Vol. XI. Pt. IV.; Verhdlg. V. Intern Zool.-Congress) of the species-question as affecting the method of recording certain data, viz. homogeneous morphological groups. The sponge species are often very homogeneous, because represented by single specimens. That such groups answer always to natural species, as we understand the word when we speak of the human race, *Passer domesti-*

cus, *Littorina litorea*, or other organisms which we know in great number, is not only open to doubt, but is excessively improbable. It is, I suppose, from this latter point of view (the envisaging clearly the *a priori* probability that sponges in general exhibit those individual and local differences which all species known intimately exhibit) that O. Schmidt was led to record in literature the existence of such species as *Farrea facunda*. Perhaps *Farrea facunda* is a "natural species," but the data at hand make such a statement only a subjective assumption. Or when the distinguished systematist Topsent expresses the opinion that five species of *Poecillastra* recorded by Sollas probably represent the variations of two or three species, one is justified in saying "perhaps, but the known specimens differ in certain definite respects." Such subjective interpretations of differences perhaps always affect the manner in which we record the occurrence of certain morphological peculiarities in association with geographical and bathymetrical site. But whereas once they were rampant, today they are reduced to a minimum, with the result, as I have said, that the *species* of modern sponge literature are strikingly homogeneous groups, which need not be thought of as always corresponding to natural races.

That this method of precise analysis is the only method capable of yielding trustworthy data, seems to me incontestable. That it may result in temporarily recording more species than exist in nature, will only trouble those who incline to the view that the one excuse for systematic zoölogy is to provide them with a handy collection of names for the animal kingdom.

The data which are thus accumulating as to the occurrence of this or that peculiarity of structure in a certain locality are growing rapidly through the labors of systematists. Scarcely begun is the accumulation of the almost equally important data (comp. Poléjaeff, Report on the "Challenger Keratosa," p. 85), as to what peculiarities of structure are due to a difference in the physiological state of individuals

belonging to the same race. Such knowledge, to be acquired through continuous observation of living individual sponges under normal and under modified conditions (experimental method) may be expected to bring about the union of many recorded *species*.—Another most important class of data can only be revealed through the physiological study of the *race*, viz. through the breeding of sponges. And with the increase in the number of marine laboratories at which observations may be carried on continuously throughout the year, the inauguration of such studies may be anticipated. —The modern statistical method of considering the differences between individuals of such groups as are procurable in large numbers is a refinement of what is commonly understood as systematic work, and a promising field for those acquainted with the structure of sponges. Such studies, by revealing the kinds and the extent of structural modifications which occur among individuals not separable into morphologically definable groups, may be expected to provide invaluable special cases for experimental study.—It is through the combination of these several classes of data that we must hope to learn the limits of the natural groups of sponges as they exist today. When such trustworthy definitions of natural groups are at hand, the facts of the geographical distribution of the species will doubtless become intelligible.

THE ATOMIC WEIGHT OF THORIUM.*

BY R. O. E. DAVIS.

The atomic weight of thorium has been determined with varying results. The values are dependent upon the analyses of the oxalates, sulphates, formate, acetate and acetonyl-acetate. The first value is due to Berzelius¹ and was obtained from the sulphate and double sulphate of thorium and potassium. The thorium was estimated by precipitation with ammonia and the sulphuric acid as BaSO₄. The value obtained was 234.8.

In 1861 Chydenius² published new determinations from analyses of sulphates, acetate, formate and oxalate. The mean of his determinations gave thorium, 233.1. Two years later in 1863 Marc Delafontaine published some researches on thorium³. His studies were particularly on the sulphates. The thorium he estimated in two ways: (1) by precipitation as oxalate and subsequent ignition, (2) by direct calcination. From his work a value of 230.3 for thorium was obtained.

The next determinations were those of Clevé⁴. His work was with the sulphates and oxalates. Next came the work of Nilson⁵ on the sulphates. Then in 1887 Kruss and Nilson⁶ published determinations. Of the most trustworthy values given by Clarke⁷ the value for thorium varies from 223.06 to 236.93, a mean giving the value 232.6.

*[Dissertation presented to the faculty of the University of North Carolina for the degree of Doctor of Philosophy.

¹Poggend Annal., 18, 398. 1829.

²Poggend Annal., 199, 55. 1863.

³Arch. Sci. Phys. et Nat. (2) 18, 343,

⁴Jour. fur Prakt. Chem., 98, 114.

⁵Ber. Deutsch. Chem. Gesell., 15, 2519. 1882.

⁶Ber. Deutsch. Chem. Gesell. 20, 1665, 1887.

⁷Constants of Nature, Part V.

Due to the great variation in values as given by different authorities and determined by different methods, and also the just criticisms which have been lodged against those methods for other elements, it was deemed advisable to redetermine the atomic weight of thorium. We began by first investigating the methods formerly used and then attempted a new method, with what success the sequel will show. In addition to the criticism to which the various methods are subject, recent investigations by Brauner¹ and Baskerville², who have been busied for years with the element, point to the complexity of thorium. Moreover the radio-activity associated with thorium is illy understood and appears not to belong to pure thorium compounds.

Of methods used the value 232.6 depends on those of the oxalate, formate, acetate and acetonyl-acetate. With oxalate, formate, acetate and acetonyl-acetate we have organic compounds with a large number of atoms in the molecules and varying number of molecules of water of crystallization present. For instance, in the oxalate we have $\text{Th}(\text{C}_2\text{O}_4)_3 \cdot 6\text{H}_2\text{O}$, and the acetonyl-acetate $\text{Th}(\text{C}_3\text{H}_7\text{O}_2)_4$; molecules with thirty-one and fifty-seven atoms in them respectively. It is at once evident that such complex molecules are not satisfactory for atomic weight determinations.

It is upon the sulphate method chiefly that the atomic weight of thorium depends, but the sulphate determinations are open to serious objections. There is objection to using any hydrated salts, because of the uncertainty of the composition. The anhydrous sulphate is objectional because of its porous and deliquescent nature. Yet there are other difficulties of much more importance than these. In most cases the ratio between thorium oxide and sulphate was established by incinerating the sulphate. This is a difficult process and it is extremely doubtful if all the sulphate can be decomposed, as it forms a protective coating of oxide.

¹London Ch. Soc. April, 10, 1901.

²J. American Ch. Soc., Vol. 23, No. 10., Oct., 1901.

In some cases the amount of sulphuric acid is determined by precipitation as BaSO_4 . This is also a very objectionable process, because of the well known property of barium sulphate to occlude foreign substances and hence should be excluded from atomic weight work. While the values obtained from the sulphate method may lie close to the real value of thorium, they probably deviate from it by several points.

From the above considerations it was first decided in this work to make some determinations by the sulphate method in order to test its accuracy. For the material used we are indebted to Dr. H. S. Miner, of the Welsbach Lighting Co., Gloucester, N. J., who generously supplied us with a large quantity of commercial thorium nitrate. This thorium we purified by several of the accepted methods of purification. Half kilo of the nitrate was dissolved in three litres of water and precipitated as hydroxide with ammonia. This was thoroughly washed, then dissolved in HCl . The solution was reprecipitated by ammonia. The other part was neutralized by ammonia until a slight precipitate persisted and the thorium precipitated by the addition of sodium nitrite. The precipitate was thoroughly washed, then dissolved in acid and the precipitation repeated.

One portion we attempted to purify by changing to the chromate, but on subsequent treatment, the chromium was so difficult to remove that this portion was not used in any of our work on the atomic weight of thorium.

Another half kilo, after precipitation by ammonia, was purified by dissolving in ammonium carbonate solution, and then precipitated by ammonia.

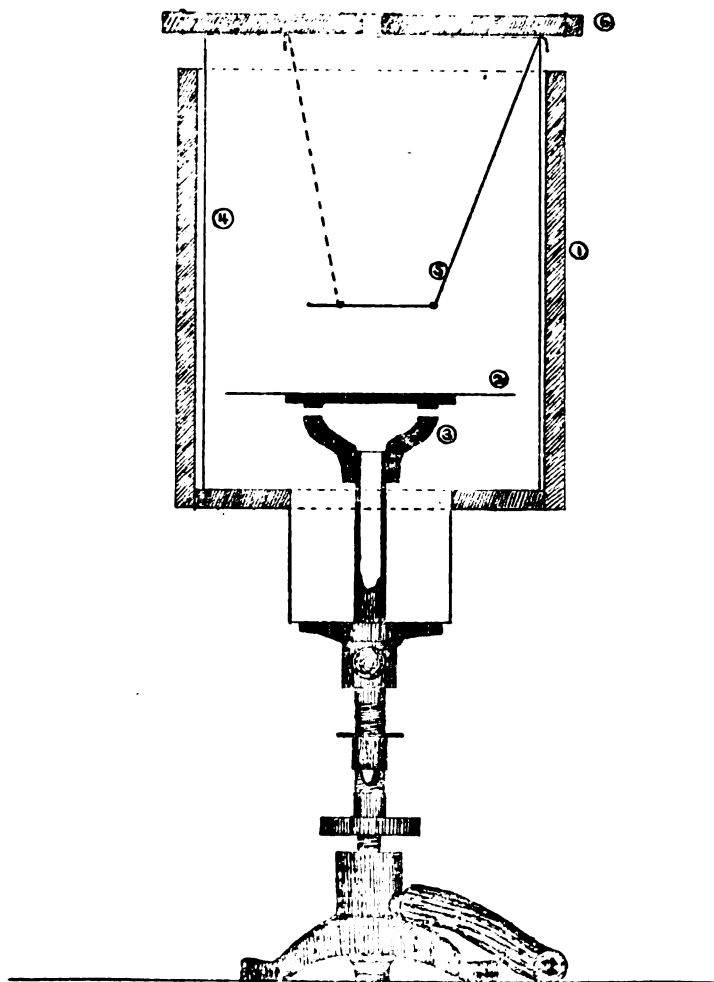
Then a portion of this precipitate was purified by the citrate method. A saturated solution of citric acid was saturated with thorium hydroxide and stirred for twenty-four hours. After the citric acid would take up no more thorium hydroxide, the undissolved hydroxide was filtered off, and the filtrate was heated in a water-bath with boiling water. A heavy white precipitate came down. This was filtered through

a hot funnel with aid of suction and washed until free from acid. From each of these different sources the thorium was used in the work to be described below.

In this work the crucibles were obtained specially for the purpose and were never used for anything else. The crucible in which the substance was weighed was counter-poised by a crucible as near the same size and weight as possible. The weights were specially standardized by the Bureau of Standards and Weights at Washington and were never used for any other work than this. The balances were adjusted to a constant load and every weight made at that load. The balances were not used for any other purpose after the beginning of this work. The weighings were made by the method of vibrations and were made to 0.000001 of a gramme.

After the purity of our thorium compounds was proven by spectroscopic examination, we first turned our attention to the determination of the atomic weight by the synthesis of the sulphate from the oxide. The method of Gerhard Kruss¹ was used. The oxide was brought to constant weight by heating with a blast lamp, then evaporating with sulphuric acid (1:1) several times to convert all the oxide into sulphate. Then the sulphate was brought to constant weight at a temperature of 360°C. In bringing the sulphate to constant weight, a bath of platinum was used. This bath consisted of a cylindrical tube of copper, about four inches in diameter, mounted above a rose burner, and lined inside with platinum and outside with asbestos. The crucible was suspended in the center of the bath by a ring of platinum wire. The temperature was taken by inserting a mercury thermometer beside the crucible. The mercury was under twenty atmospheres of pressure by carbon dioxide, and the thermometer was graduated to 560°C. It was standardized at the Reichs Anstalt. The results were not strictly concordant and an investigation showed that the ratio between oxide and sulphate varied with the temperature.

¹Chem. News, Jan. 30, 1898. Pp. 32.



(1) Copper Cylinder, sheathed with Asbestos, resting on three-armed Support, clamped to Bunsen Burner. (2) Platinum Plate, resting on Rose Burner, (3). (4) Platinum Cylinder resting on Asbestos Mat. (5) Platinum Triangle, supported by Platinum Wire Hooks. (6) Asbestos Cover, lined on the inside with Platinum; Hole in center for Thermometer.

Our work seems to indicate that in the formation of the sulphate a mixture is formed. The portion of the sulphate next to the crucible may have been decomposed while the inner portion would still be acid sulphate. Since the atomic weight determinations carried out by other investigators were not made at a definite temperature, then from our investigations the values might have a wide range. Of course, if a series were carried out under exactly the same conditions, concordant results would be obtained. But still there would remain the question whether all the body was normal sulphate or acid or part acid and part basic.

The determination of the equivalent from the acetonyl-acetate next claimed our attention. The crystals of acetonyl-acetate were made, but they showed two forms of crystals so that they were not used. The obvious disadvantage of using such a compound has already been mentioned.

After considering the various methods upon which the equivalent of thorium is dependent we decided to try a new method. Of the compounds of thorium considered the tetrachloride seemed to offer the greatest advantages. By its use the ratio could be determined between the oxide and the chloride, and the values of only three elements would be involved.

The thorium oxide was ground up in an agate mortar with carbon (about one-tenth the weight of the oxide) and the mixture placed in a carbon boat. The boat was placed in a hard glass tube passing through a combustion furnace and while heated to a good red heat, dry chlorine passed through the tube. Beautiful crystals of the chloride formed on the walls of the tube just beyond and above the boat. Still farther, lighter and feathery crystals formed in the tube, and a white vapor, Berzelius's "Weisserdampf", was driven off and caught in alcohol.

The carbon used was obtained by heating crystallized rock candy. The boats were previously heated in a stream of dry chlorine for several hours. The chlorine used was taken from

an iron cylinder, and was analyzed for oxygen and other impurities. About two per cent. of an inert gas was found, but it was not deemed necessary to remove it. The chlorine was dried by passing over a train of eight towers and wash bottles containing sulphuric, and two towers with glass beads and sulphuric acid, then finally through five towers with glass beads and sulphuric acid, this being the apparatus used by Richards¹ in his work on the atomic weight of cobalt and nickel.

The method of determining the ratio between the chloride and the oxide was to weigh the chloride, dissolve in water and evaporate in a platinum crucible, then ignite to constant weight. The portion of the tube in which the crystals were formed was cut out and slipped quickly into a weighing bottle and then placed in an air bath at 160°C. to drive off the chlorine. It was then removed and placed in a dessicator and after an hour weighed. After weighing the chloride was dissolved in water and then the tube returned to the weighing bottle and brought to constant weight. This gave the weight of the thorium tetrachloride.

The solution of thorium tetrachloride was evaporated in a platinum crucible on the water bath, then ignited to constant weight. In order to bring to constant weight the oxide had to be blasted about seventy hours. This gave the weight of the oxide derived from a given amount of the chloride. But no constant relation could be obtained.

Thinking that perhaps the difficulty lay in not being able to drive off all the chlorine by heat and ignition, we turned our attention to the determination of the halogen. A long series of experiments investigating a new method for the determination of the halogen was begun. Since silver chloride is soluble in water to a certain extent, we decided to investigate its solubility in alcohol.

The alcohol used was absolute and freed from aldehyde by fractional distillation until it would not respond to the fus-

¹Proc. Amer. Acad. Arts & Sci. Vol. 34, No. 18, Pp. 832, 1889.

chine test, which shows one part in a million. Silver nitrate solution was made by dissolving pure silver prepared according to the method of Stas by Venable, in pure nitric acid. A solution of $\frac{N}{10}$ NaCl was made for determining the chlorine.

Several series of experiments were carried out to determine the effect of an excess of silver nitrate in solution, of acidity, and of temperature. The temperature was varied from boiling to room temperature (about 23°C.).

One cubic centimeter should have precipitated 0.0143 gm. of AgCl. The following are some of the results.

10. AgCl found, 0.756, theoretical, 0.1716; Temp. 30; excess of AgNO₃ 0.1028; acidity, 18.5 cc. $\frac{N}{2}$ acid.

12. AgCl found 0.1732, Temp. 30; excess AgNO₃ 0.2399; acidity, 20.4cc. $\frac{N}{2}$ acid.

14. AgCl found 0.1800, Temp. 78; excess AgNO₃ 0.2183; acidity 25.6cc. $\frac{N}{2}$ acid.

18. AgCl found 0.1754, Temp. 60; excess AgNO₃ 0.0171; acidity 25.6cc. $\frac{N}{2}$ acid.

There were twenty-five determinations carried out, all giving too high results, as may be seen from the figures given. By another series of experiments carried out at thirty degrees with rapid filtration, it was found that the results in general agreed with the theoretical. But the conditions were very hard to attain.

We now returned to our thorium and made a series of experiments to determine the chlorine of the tetrachloride. But the results were not concordant, which fact was explained by finding that even aldehyde-free alcohol decomposes silver nitrate, causing finely divided silver to deposit. Of course this method was immediately abandoned.

Now once again we turned our attention to determining the

ratio between the chloride and the oxide of thorium by direct evaporation of the chloride solution and the subsequent ignition of the residue to the oxide. But noting that the hard glass tube, in which the chloride was formed, seemed to be attacked by the chlorine at the temperature required for the formation of the chloride, it seemed possible that the disagreement of our values might be due to the formation of other chlorides from the glass. A series of experiments confirmed this view that the glass was causing a contamination of our thorium compound. Hence we set about to eliminate this trouble.

Quartz tubes were imported especially for the work. These were about 2 cm. in diameter and 25 cm. long. In one end of one of these was placed the carbon boat with the mixture of carbon and thorium oxide, and the whole inserted in a porcelain tube and placed in the furnace. The porcelain tube was heated while a stream of dry chlorine was passed through. The "Weisser-dampf" settled on the walls of the porcelain tube, near the end, and the crystals of tetrachloride formed in the quartz tube.

For weighing the chloride, special weighing bottles, 39 cm. long, were obtained. Into one of these the quartz tube was quickly inserted on withdrawing it from the porcelain tube, and after removing the carbon boat. A second weighing bottle was used as counter-poise. The solution of the chloride was evaporated and the final ignition to constant weight was the same as when the glass tubes were used. The water used for the solution of the chloride was purified by redistillation in a platinum still.

The quartz tubes also showed signs of attack by the chlorine at the high temperature used, and so the oxide, after becoming constant in weight, was treated with hydrofluoric acid and the loss in weight, usually very small, applied as a correction to the weights of both the chloride and oxide.

Using every precaution in the work we still failed of constant values, most of them falling between 221 and 230; yet

some came lower and some higher than those values. The crystals that seemed to be purest gave values within the limits named. From the inability to obtain a constant value, it seemed that the crystals of chloride must be contaminated. It will be remembered that the crystals of chloride were the middle portion in the formation of the chloride: that is, a light "Weisser-dampf" passed to and condensed on the front of the tube, just beyond the boat were the crystals of the chloride used for the work, and there still remained a residue, mixed with the carbon in the boat, that could not be volatilized. In other words, by distilling thorium oxide in chlorine, three fractions were obtained.

After the first distillation was performed, a determination of the equivalent of each of the end products was made by the sulphate method. The following results were obtained:

Oxide from non-volatile part.	sulphate.	At. Wt.
1.636725 gm.	2.595223	241.44.
Oxide from most volatile.		
0.794692	1.309245	212.70.

As the complexity of thorium had been indicated by Baskerville and the name "Carolinium" proposed for the heavier element, we have applied the name of Carolinium to the heaviest portion. For the lightest the name "Berzelium" was used, and Thorium for the middle portion.

After the redistillation of our carolinium, thorium and berzelium fractions three times, a determination of the atomic weight of each was made by the sulphate method. In changing the oxide into sulphate, sulphuric acid (1:1) was used. This was then carefully evaporated. The berzelium seemed to be rapidly changed; but the thorium and carolinium were more persistent, requiring about four evaporations. In every case sulphuric acid was added and evaporated at least four times, to be sure that all the oxide was converted into sulphate. The carolinium sulphate was perfectly soluble in

water, thus showing that all the oxide had been converted into sulphate.

Two determinations of each, carolinium, thorium and berzelium were run at the same time and subjected to the same conditions as nearly as possible. The sulphate of each was heated at 350°C. to constant weight. The platinum bath already described was used and also some large porcelain crucibles with a platinum ring suspended in the center to hold the crucibles. The crucible with the sulphate was placed on this ring, the large crucible covered with a punctured clock glass, and a thermometer suspended through the hole in the glass just above the sulphate inside the small crucible containing it. The results obtained are given below.

The oxides of the three fractions were different in appearance. The carolinium invariably was gray with pink tinge, the thorium slightly greenish, and the berzelium a little more pronounced green. The sulphates of all are pure white when cold, but that of the thorium is yellow while hot.

The following are the results from the determinations:

(1) Carolinium.

Oxide.	Sulphate.	At. Wt.
1.559290	2.434914	255.5
0.524254	0.819365	255.9
0.549331	0.854810	255.6

(2) Thorium.

Oxide.	Sulphate.	At. Wt.
0.425456	0.694936	220.62.
0.740052	1.210405	220.1

(3) Berzelium.

Oxide.	Sulphate.	At. Wt.
0.306778	0.507505	213.6
0.320618	0.530890	212.0

From this it seemed that we were accomplishing the sepa-

ration of the thorium into three fractions of different atomic weights. The atomic weight of genuine thorium is therefore not yet established.

I wish to express my sincere thanks to Professor Chas. Baskerville not only for his sympathy and assistance in the work, but for the privilege of taking part in an investigation, which has been so fruitful in its results.

University of North Carolina.

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NO. 2

PROCEEDINGS OF THE FOURTH ANNUAL MEETING
OF THE
NORTH CAROLINA ACADEMY OF SCIENCE

HELD AT

A. & M. COLLEGE, RALEIGH, N. C., MAY 12-13, 1905.

MAY 13, 1905.

Meeting called to order by President Stevens at 8:30 P. M., but adjourned for informal conference during which a number of matters were discussed.

MAY 14, 1905.

Meeting called to order at 10 A. M. by President Stevens, who at once appointed Messrs. C. S. Brimley and W. C. Coker as Nominating Committee.

Upon proper presentation of names, Messrs. G. M. Bentley, of the North Carolina Department of Agriculture, at Raleigh, and J. G. Boomhour, of the Baptist Female University also at Raleigh, were elected members.

The Academy then proceeded to the presentation of papers, which were given in the following order:

[Issued September 20th, 1905.]

1. ABNORMALITIES IN THE EMBRYO-SAC OF *LILLIUM TIGRINUM*: *F. L. Stevens.*

Three abnormalities were noted. In one case the nucleus at the micropilar end of the embryo sac was undergoing constriction while in the spirem stage without any sign of spindle formation. In another case five nuclei, three of these cut off by walls, were in the antipodal end of the embryo sac. Another slide exhibited an excessively long nucleus in the micropilar end of the embryo sac. No explanation was offered. Slides showing the structures referred to were exhibited to the Academy.

2. NOTES ON THE FOOD AND FEEDING-HABITS OF SOME NORTH AMERICAN REPTILES: *C. S. Brimley.*

Personal observation describing how a snake swallows an animal or egg apparently too large for such process. Mentions the food upon which snakes, lizards and turtles have been observed to feed. Describes how a king snake kills another snake.

3. ON THE RECORDED DISTRIBUTION OF CERTAIN INJURIOUS INSECTS IN NORTH CAROLINA: *F. Sherman, Jr.*

Attention was called to the value of positive data concerning the distribution of injurious insects determining the probable results of sporadic out-breaks and informing the prospective planter or orchardist of the pests to be encountered in any particular locality. The Division of Entomology of the North Carolina Department of Agriculture has been keeping accurate records of all reported insect outbreaks for over four years. Some species appear to be generally distributed, others so meagrely recorded as to furnish no conclusions as yet, while still others show fairly well-defined limits.

Notes and maps to illustrate distribution were given as follows:—*Chinch Bug* occurs probably throughout the state east of the mountains, but most destructive in the piedmont section. *Corn Bill-beetle*, probably occurs throughout eastern half of the state, but is chiefly destructive along rivers and streams subject to overflow in the eastern section. *Oyster-shell Bark-louse*, probably occurs throughout the moun-

tain and piedmont sections, but chiefly destructive in the mountains. *San Jose Scale*, occurs in various localities in all sections of the state and has been spread largely by shipment of infested plants. *Strawberry Weevil*, occurs in the strawberry-growing region in the southeast with questionable records for the counties of Wilson, Richmond, and Buncombe.

4. A NEW APPLE-TREE DISEASE. *F. L. Stevens.*

A disease designated as scurf was described. It is an infection of the bark on young twigs, causing a wrinkling and cracking, somewhat resembling the San José scale in appearance. The fungus causing this disease was exhibited in pure plate and tub culture before the Academy. Inoculation experiments are in progress, and a canvas of the state is being made in order to determine the extent of distribution and seriousness of the disease.

Remainder of the papers were withheld to be read at the Joint Session with the North Carolina Section of the American Chemical Society.

The Academy then proceeded with the business of the regular business meeting and upon report of the nominating committee and by ballot the following officers for the next year were elected:

President, PROF. JNO. F. LANNÉAU, Wake Forest.

Vice-President, DR. TAIT BUTLER, Dept. Agr. Raleigh.

Secretary-Treasurer, DR. F. L. STEVENS, A. & M. College, West Raleigh.

Executive Committee:—PROF. JNO. F. LANNÉAU, *ex officio*, DR. F. L. STEVENS, PROF. COLLIER COBB, Chapel Hill; MR. H. H. BRIMLEY, Dept. Agr., Raleigh; MR. F. SHERMAN, JR., Dept. Agr., Raleigh.

At this point the members of the Chemical Society entered and the Academy proceeded to the business of the joint session, at which the following papers were presented:

1. THE SCIENCE OF PLANT PATHOLOGY, (Presidential Address of President) *F. L. Stevens for the Academy.* (Appears in full in this issue.)

2. A NEW COLOR REACTION FOR LIGNOCELLULOSE:
A. S. Wheeler.
3. PHYSICS OF SHOOTING STARS: *Jno. F. Lanneau.*
4. CORROSION OF IRON: *R. O. E. Davis.*
5. CONDENSED FORM OF FAT EXTRACTOR AND ETHER
RECOVERER: *J. M. Pickel.*
6. BUTTERFLIES OF RALEIGH, N. C.: *C. S. Brimley.*
In this paper the number of species belonging to each
of the families of butterflies was enumerated. Paper
was illustrated by specimens prepared in Riker
mounts.
7. A PHARMACIST'S VIEW OF PATENT MEDICINES: (summar-
ized only) *E. V. Howell.*

At the conclusion of this program President Williams of the Chemical Section announced the adjournment of both bodies to Giersch's Café where a lunch was tendered the visitors by the Raleigh members of both organizations.

FRANKLIN SHERMAN, JR.,
Retiring Secretary.

THE SCIENCE OF PLANT PATHOLOGY.*

BY PROFESSOR FRANK LINCOLN STEVENS, PH.D.,
North Carolina College of Agriculture.

From the time men first had interest in plants, knowledge of their imperfections or premature death has existed, without, however, definite conception that the imperfections in question really constitute a condition of disease.

The Bible and the early writings of the Greeks and Romans contain references to what we now recognize as wheat rust, fig blight, insect galls and other of the more strikingly conspicuous plant ailments. Such references are more abundant in the literature of the seventeenth century, and in the latter part of that and the eighteenth century a few papers giving careful descriptions of malformations due to insect invasion appeared. Even the law was invoked to aid in combating the wheat rust in France as early as 1660. Prior to the nineteenth century, however, knowledge of plant diseases can hardly be said to consist of more than mere observation of the fact that such diseases occur, and the little real knowledge that did exist was swamped by rampant superstition.

It is natural that the first attempts to explain imperfections were founded upon climatic and soil relations. Vestigial beliefs prevail to this day throughout the country among the untutored to the effect that the various blights, rusts, rots, mildews, etc., are caused solely by untoward conditions of weather, or the unpropitious position of celestial bodies or some other occult influence.

The significance of one great factor in the production of plant disease, namely the parasitic fungi, remained quite unrecognized until the second decade of the nineteenth cen-

*Reprinted from *The Popular Science Monthly*, September, 1905.

tury. Fungi had been seen upon the plant and had been described in some detail during the preceding decade, but instead of being recognized as casual agents of disease they were, as was the fate of bacteria in the case of animal diseases, by many regarded as products of disease. Before the study of plant diseases could be scientifically undertaken, the basic facts of plant nutrition were to be discovered, the parasitic habit of the fungi proved, the minute anatomy of the plant disclosed. Epoch-making in the disclosure of these desiderata, which may be said to have given birth to plant pathology as a science in the second decade of the nineteenth century were the investigations of the early Dutch, French, German and English botanists. Like bacteriology, plant pathology is an infant science of the last century, owing its being to the perfection of the microscope.

In the last two decades of the last century, scientific effort concerned itself chiefly with accumulating knowledge concerning fungi and insects. Vast numbers of these were classified, catalogued and described. In other words, the means of diagnosis were perfected and diseases were grouped into natural classes according to their casual agents. Attempts toward the development of methods of treatment by the use of various sprays were more or less effective. Indeed, spraying had been advocated to some slight extent for a century or more as a remedy for insect and other plant diseases. The variety of spraying substances ranged from clay, ashes and cow manure to sulphur, lime, salt, etc. One writer recommended "The applying around the base of the tree; flax, rubbish, sea weed, ashes, lime, sea shells, sea sand, mortar, clay, tanner's bark, leather scraps, etc."—evidently not a homeopathic prescription. The variety of substances recommended raises suspicion that the efficiency of no formula was demonstrated. In 1787 we find the heroic advice, 'just wet the trees infested with lice, then rub flowers of sulphur upon the insects, and it will cause them all to burst.' Some decided progress was, however, made. As early as 1842, a whale

soap was used and retained favor; quassi, hellebore and tobacco were standard insecticides as early as 1855. Sulphur was used for the mildews and bluestone for wheat smut.

The last twenty years of the nineteenth century mark the beginning of a new epoch in plant protection. For this there are three reasons: first, the increased aggressiveness of a certain fungous disease, the grape mildew, in Europe; second, the rapid spread of the potato bug, somewhat pedantically termed the Colorado beetle, and, third, resulting from these two, revolutionary changes in materials and methods for treating plant diseases, both fungous and insect, in the new world and in the old. It is a matter not entirely without interest that the revolution in European methods may be definitely traced to typical American aggressiveness, inasmuch as the activity arousing fungus was of American importation.

In Europe the invasion of the downy mildew of the grape in 1878 was unchecked by the most vigorous fungicides then used. All are familiar with the story of the great benefit conferred upon humanity through the predatory habits of the French boys in the vineyards that produce the famous Bordeaux wines. The rows lying nearest the roadway were sprinkled with verdigris or a mixture of lime and bluestone, to give the impression that the fruit was poisoned. In 1882 Millardet, of the faculty of the sciences, noticed that the vines thus treated held their leaves while others succumbed to the mildew. He ascribed this effect to its proper cause, and conducted carefully systematized experiments, which resulted in giving to the world *bouillie bordelaise*, *Bordelaiser Bruhe*, or Bordeaux mixture, a proved fungicide of great efficiency; one that has not yet been surpassed.

In the new world the extension of the potatoe belt westward connected the eastern potato belt with the region of the native food plant of the familiar potato bug. Finding the potato plant a more abundant and wholesome food than the wild solonaceous plants that it had formerly fed upon, the

potato bug began its eastern migration. In 1859 it was found east of Omaha City, in 1868 it had reached Illinois, in 1870 Ontario, in 1872 New York and in 1874 it was upon the Atlantic seaboard. The potato bug ate ravenously and man was stimulated to new activity in the search for more effective means to overcome insect pests. The use of Paris green and London purple followed as a direct result of this stimulus.

The development of efficient fungicides and insecticides in Europe and America led naturally to the perfection of the machines used in applying these mixtures, and not the least important part played in the development of a practical plant pathology is concerned with the evolution of spraying machines. The first sprayer consisted of a bunch of switches. This was dipped into the spraying mixture which was distributed over the foliage by vigorous shaking. It gave place to an improved spraying broom or brush with hollow handle, the liquid flowing from a reservoir to the brush, from which it was applied to the leaves. Sprayers and pumps followed in turn. Then came the improvement of the nozzle.

We may recognize two periods in the development of plant pathology: the first or embryonic period extending from pre-historic times to the beginning of the truly scientific investigations in the middle of the eighteenth century, and contributing chiefly observations, collections, descriptions; the second or formative period, during which the foundations of the science were laid, the chief factors of it determined, and the chief lines of future progress marked out.

It is in no way my purpose to call attention to the part the Carolinas have played in botany as a science, yet I can not refrain in passing from mentioning that prominent place in the history of American mycology is assured to de Schweinitz, a minister of Salem, N. C., who in 1818 published the first important paper on American fungi; to M. A. Curtis, a tutor in Wilmington, N. C., who in 1830, with Berkeley in

England, described many fungi of the Carolinas; to Ravenal, of South Carolina, the first to publish exsiccati of American fungi, and to Louis Bosc, of South Carolina, who published a descriptive list in 1811.

The embryonic and formative period prepared the way for the third period, beginning about 1885, which may be called the period of growth. It is marked by the development and perfection of the rudimentary principals and discoveries of the preceding periods. It was during this period that the most spectacular conquests were made; that popularization and extension of methods occurred. So great, so numerous, so wonderful were the advances made during the past decade, that we frequently see the statement that little or no progress had been made in plant pathology prior to 1885. The present day student should, however, bear in mind that it was the persistent, arduous, patient work of the preceding years that rendered possible the progress of the closing years of the century.

My denomination of this period as 'the period of growth' indicates the nature of the changes which it inaugurates; growth in every direction and concerning every phase of the subject. There has been growth in the list of plant maladies. New diseases have been discovered by scores, and old diseases have been found to affect new plants, and diseases hitherto insignificant have taken prominent places as dangerous foes. The alteration of the plant constitution by high selection and breeding, the bringing of plants into new climatic or soil relations, the more intensive cultivation, the bringing of a susceptible plant into a region where a parasite is already growing upon one of its botanical relatives, thus exposing it to a possible new foe, are conditions that operate to admit of the evolution of new diseases. The growing of plants in large quantities in solid blocks, rather than sparingly in scattered gardens, brings about a congested condition comparable with the crowding of our cities, and favors

the development of epidemics* by furnishing abundant material for the parasitic organisms to attack, abundant nutriment upon which they may multiply, and abundant opportunity for them to reach new hosts and spread the contagion. With potatoes, for example, raised merely as garden crops, the probability of an epidemic affecting the majority of gardens is not so great as when potatoes are raised in vast fields. A single field crop, once infested, so contaminates the air with spores that other fields are almost sure to become infected. The contagium becomes sufficiently multiplied to break the quarantine, and a general epidemic results. Any factor which tends to increase the occurrence of epidemics may quickly raise a given disease from obscurity to a position of commanding importance. So, too, does the increase in value of hitherto comparatively insignificant crops. The pecan and cranberry are at present objects of particular solicitude by the plant physician.

With the importation of plants from foreign countries and the transportation of plants from one part of the country to another comes the possibility of increased disease transference. Recent years have seen the San José scale spread from the Pacific to the Atlantic; the asparagus rust from the Atlantic to the Pacific; the hollyhock rust has invaded us from Europe; the chrysanthemum rust from the Orient; the watermelon wilt is now moving northward and the peach yellows southward. In nearly all cases where the soil is diseased the affected region is annually enlarging, so that soil diseases a decade ago insignificant in the territory of their occupation are fast assuming control of alarmingly large regions. The growing of plants in larger quantities also increase the amount of germ-bearing refuse to the ultimate end that the very air and soil become germ laden.

Civilization, higher culture and community life, especially

*The use of the word epidemic in relation to plant diseases while etymologically incorrect, seems justified since no other word conveys the desired meaning and the meaning of this word is clear to all.

if it verge upon congestion of population, exacts an inevitable forfeiture by increased mortality. Thus does the list of diseases that comes within the horizon of the practical men enlarge. Wonder, often scepticism, is expressed at the existence of unfamiliar diseases of man, other animals and plants, as though these afflictions were conjured up by the examination of the over zealous practitioner. The increase of affliction is more apparent than real, as it is in the case of appendicitis, which is now recognized, named and cured, consequently, heard of, whereas under the old régime it was not recognized as a distinct disease, therefore it was unheard of, though the patient died. Parallel cases might be cited among the plants.

The work of DeBary on polymorphism among the fungi is being extended. Knowledge of the life histories of various pathogenic fungi is being slowly expanded. Summer forms are connected with winter forms, and thereby the hibernating condition, often the most vulnerable point of attack, exposed. The discovery of heteroecism in the rusts, the alternation from wheat to barberry, from apple to juniper is of classic antiquity in the annals of plant pathology. It emphasized the need of close study of life histories of all parasites. Such study has given abundant fruit, notably in disclosing the relation between the apple cankers and the bitter rot of the apple, and revealing the winter condition of the brown rot of the peach. The lead so fortunately made in the discovery of the Bordeaux mixture has been assiduously prosecuted. The original Bordeaux mixture has been greatly modified, changed, indeed, from a thick paste to a thin solution, and so thoroughly tested in all its modifications, that it has now reached its ultimate perfection. Hundreds of other chemicals, both dry and wet, have been tested as fungicides, with the adoption of a few adapted to special conditions, *e. g.*, sulphur and sulphides for powdery mildews and the ammoniacal copper carbonate for use as the fruit ripens, thus avoiding unsightly spotting. A happy combination of insecticide and

fungicide has been found in the various sulphur washes. There has been very remarkable growth in the perfection of spraying appliances; pumps and dusters of many kinds are upon the market. Particularly is the improvement in nozzles to be noted. Nozzles constructed upon scientific principles, capable of applying the liquid in the form of the finest spray to the tops of the highest trees. In the place of the old hand pump and pail we find barrel pumps on wheels, tanks on wheels with pumps operated by gearing attached to the wheels, and finally for the larger fruit farms and for municipal care of shade trees are multiple pumps driven by steam power.

The treatment of seeds to kill adhering spores has been improved upon in many details. It illustrates especially well the nature of the development during the present epoch of plant pathology. Originally the treatment for wheat smut was based purely upon superstition. Pliny, for example, says that 'if branches of laurel are fixed in the ground the disease will pass from the field into the leaves of the laurel.' Tull in 1730 says that there are but two remedies proposed, brining and changing the seed. The avoidance of certain kinds of manure because of their effect upon the host plant and because they carried the smut spores was also advocated about that time. The scientific demonstration by Brefeld that the plant is susceptible only when very small, gave rise to the thought that by hastening the early growth the period of susceptibility could be shortened, and methods of planting and tilling in accord with that idea were advocated. In addition to cultural methods mechanical treatment of seeds, such as passing the wheat loosely between millstones, violent fanning, etc., were suggested about 1786. The chemical treatment of seeds, says Tull, was accidentally discovered about 1660 by the sinking of a shipload of wheat at Bristol, and afterwards, finding it unfit for breadmaking, it was used for seed wheat. The following harvest in England was very smutty except in the case of this accidentally brined seed,

which made a clean crop. Then followed brining with liming and liming without brining, soaking in lime, arsenic, salt, arsenic and lye, and various other treatments, none of which, however, came into general use. Accident coupled with acumen again aided in hastening a discovery. Provost while attempting to germinate some spores placed some of them in water distilled in a copper vessel. These failed to germinate, though similar spores placed in water which had not touched copper germinated well. Following this lead he and numerous other investigators experimented extensively with copper compounds during succeeding years.

Such is the history of the development of a treatment effective for smut of wheat and barley, but not for that of oats. The next marked advance was made by Jensen, a Dane, who in 1887 developed the famous Jensen hot water treatment, a treatment which though requiring considerable accuracy of manipulation was thoroughly effective. This method, if no easier were to be had, was well worth to practical agriculture all that the experiment stations of the world have ever cost. Within only a few years, however, the Jensen treatment was supplanted by the formalin treatment; a treatment so simple, inexpensive and effective that, save for minor improvements of detail, the end seems to have been reached in the search for preventives for the particular diseases to which the method applies.

Growth of knowledge concerning bacterial diseases has occurred, beginning with the pear blight which baffled all horticulture prior to the assertion of its bacterial nature by Professor Burrill. The proof that bacteria can and do cause plant diseases has been definitely adduced, and a large number of such diseases have been recognized upon many plants. Not only from the scientific side have these ailments been studied, but from the practical as well, and preventive and palliative measures have in many instances been found.

The soil is often spoken of as the living earth. Not only may it live, but it also partakes of those chief accompani-

ments of life, viz., health, sickness and death. A healthy soil may, from an agricultural point of view, be regarded as one capable of fulfilling all its vital functions; a sick soil, one in which some functions are impaired. Of only one class of soil sickness may I speak, namely, that which results in producing sick plants by harboring pathogenic germs. The cotton wilt, the Texas root rot, the watermelon, tobacco, tomato and cabbage wilts, the cabbage club foot and the onion smut are conspicuous examples of diseases so propagated. Diseases of this type not only destroy the crop, but they preclude the possibility of successful culture of the plant in question, or of its close botanical relatives for many years. Such foes to agriculture have completely destroyed the possibility of tobacco growing on many farms otherwise eminently adapted to this crop and ill adapted to any other, resulting in great depreciation in the value of the land. This encroachment upon valuable soil will proceed yearly, and with geometrically increasing rapidity, until means of prevention are discovered, as they have now been in some instances, and the method of prevention becomes common knowledge. Soil diseases, the most dreaded of all dangers to the plant, are prevalent to much greater extent in the south than in the north. One field is known to exist in South Carolina upon which neither melons, cotton nor cow-peas can be grown. It is conceivable that many other germs could infest one and the same field, but no greater affliction concerning such staple crops seems possible.

Growth in popular appreciation of the importance of plant diseases and of the value of remedial and prophylactic measures is perhaps the most striking characteristic of plant pathology in the last twenty years. At the beginning of this period spraying was in no wise general. It was of rare occurrence. Man suffered unresistingly the attacks of the molds, mildews, rots and blights. The circulation of thousands of state experiment station bulletins and similar bulletins from

the national department of agriculture, the vigorous campaign of farmers' institutes, farmers' reading circles, farmers' extension courses, and the extended use of farmers' periodicals and agricultural papers have served to bring the latest discoveries of science to the use of him who will heed. As is to be expected, it is the man who most closely studies his business, he who has most at stake, the large specialist in the culture of any crop, who first embraces the offered aid. The orchardist or vineyardist leads the way in the adoption of new methods and new machinery. The revolution looking toward recognition of the value of plant treatment is now so thoroughly inaugurated that the treatment of such diseases, both insect and fungous, in the case of fruit and trucking crops is of general occurrence. The movement, too, is world-wide.

The practical outcome of all the investigation and propaganda up to the present time is that many hundreds of plant diseases have been recognized; for a hundred or more have been prescribed remedial or preventive measures, many of which are eminently successful; witness, the treatment of cereal smuts, the peach curl, the grape black rot, the powdery mildews. The saving occasioned by any one of these, as is true of scores of others, would amply suffice to pay all the expense of investigation and propaganda incurred in the development of the whole field of plant pathology. By oat smut alone the estimated damage in the United States yearly is \$26,766,166, a loss avoidable by an annual expenditure of less than four cents an acre. The saving actually made in Dakota, Minnesota and Wisconsin in one year is placed at \$5,000,000.

The future problems of plant pathology are manifold. The period of growth must continue long before the work now undertaken is done. Many diseases of even the cultivated plants are not yet recognized. The diseases of wild plants, particularly the weeds, must too be studied to ascertain the possibility of intercommunication of diseases between

weeds and crop plants. The life histories of all disease producing fungi must be closely studied, particularly to determine their hibernating condition. As yet the merest beginning has been made. The interrelation of host and parasite must be studied, the periods, points and modes of infection made known. The biology of the fungi, their life habits, conditions of spore formation, characters of growth, relation to light, heat, moisture, nutriment, etc.; their resistance to adverse conditions, their longevity under various conditions of environment are all problems of ultimate practicality. The question of species is unsettled and the recent demonstration of biologic varieties among the rusts, mildews and fusariums opens a large and important field of research. The agencies operating as disease distributors, the wind, insects, soil, man, water or what not must be known that such distribution be more readily controlled. The causes of resistance and susceptibility to certain diseases rest in obscurity, except in a few cases where the responsibility has been fixed upon some particular structure or chemical. The breeding of plants resistant to specific diseases not readily amenable to other means of control must proceed. Such work is now in progress with cotton, melons, tomatoes, tobacco, grains, flax and other plants. The relation existing between many root fungi and bacteria and the roots they inhabit remains to be studied. Aside from parasitism there is also mutualism, a kind of beneficial disease falling to the province of plant pathology. It needs much further study.

Specific problems also abound, the peach yellows and rosette, the mycoplasma theory of rusts, the grape Brunnisure. Differences of opinion now exist on the technique or scientific data are insufficient for an adequate solution of these questions and many other similar ones. Work on timber protection, while not strictly a question of disease, but rather a post-mortem problem, falls to the lot of the pathologist for the want of a more appropriate place. That intensive study

of a disease, however thoroughly it may seem to have been studied before, may lead to important development is well illustrated in the case of the familiar pear blight, which, though known for ages and the topic of masterly classic research, has recently, under trained observation and critical interpretation and experimentation, revealed new secrets leading to more masterful and complete control. The large fields of plant pathology, grouped under the term 'physiological disorders,' are still practically unworked; diseases due to false nutrition, absorption or assimilation, or to impaired carbon assimilation owing to improper environment, to crowding or shading or to hereditary inabilities. A start has been made sufficient to show the importance of the results awaiting.

The recent discovery of the ultramicroscopic organisms or filterable enzymes which has robbed the bacteria of the distinction of being the smallest of living things opens a new field in both plant and animal pathology comparable in kind, though probably not in magnitude, with the creation of bacteriology by Pasteur. It is yet unknown whether we have to do here with organisms or enzymes, and contemplation of the problems awaiting in this realm places us in a position to appreciate more fully than ever before the great controversy of spontaneous generation as fought in the sixties. The announcement in a recent periodical of the discovery of soluble protoplasm emphasizes the existence of a vast unknown covered by the words protoplasm, enzymes, invisible organisms. Is it coincidence of fate that with the growing importance of the problem of the invisible organism there comes the invention of a microscope of surpassing excellence with which the seeing of molecules is a hoped for possibility?

The science of plant pathology is indeed young. It has yielded much, and it is still full of promise. In the achievement of the results to come draught will be made upon the sister sciences even more than in the past. Plant physiology

waits upon chemistry; plant pathology upon plant physiology, and chemistry in return receives valuable contribution from both. Mathematics, physics and geology all contribute to the general upbuilding. The sciences, though becoming more divergent instead of becoming more independent, are yearly becoming more dependent, each using the discoveries of the others to gain new foothold or new tools in the search for truth. Often it is the frontier territory lying between two sciences which, belonging distinctively to neither, is least worked, and therefore presents most promising territory for conquest. Such is the history of the comparatively new sciences of physical chemistry, physiological chemistry and biometrics.

Nor does the field belong exclusively to either the devotee of pure science, so-called, or of applied science. The study of problems seemingly most remote from any practical ends has often proved fundamental in the upbuilding of vast industrial growth. Bacteriology was born of crystallography. The father of galvanic electricity was derided as the frog's dancing master. Nor does the avowed object in view give a sure key to the ultimate outcome. Alchemy, though never attaining the end sought, hastened immeasurably the era of industrial chemistry. Nor may it be said that applied science is inferior, for without the application the fundamental principles are of no avail in the promotion of the welfare of man.

Intensive laboratory study with no object other than the increase of knowledge of molecular construction has led to the commercial production of many important compounds. The present oat smut treatment by formalin owes its practicability equally to pure science in the chemical study that rendered the production of formalin practicable at moderate cost, and to pure science of the botanist who from mere interest in fungous growth discovered the nature of parasitism, and to the practical scientist who applied the knowledge of the chemist and the botanist to the solution of a

definite agricultural problem. The distinction between pure science and applied science is invidious. It is not a difference based upon the nature of the knowledge; rather upon the motive of the worker. All true science is practical, either remotely or directly, and the man of applied science is but completing the work of the pure scientist. Especially does the future of plant pathology rest with both.

A MEMOIR ON THE TWENTY-SEVEN LINES UPON A CUBIC SURFACE.

ARCHIBALD HENDERSON, PH.D.

HISTORICAL SUMMARY.

Although it is probably true that the classification of cubic surfaces is practically complete, the number of articles yearly appearing upon these surfaces furnish abundant proof of the fact that they possess much the same fascination as they did in the days of the discovery of the twenty-seven lines upon the general cubic surface. The literature of the subject is very extensive and in a bibliography* on curves and surfaces, compiled by J. E. Hill, of Columbia University, the section on cubic surfaces contained 205 articles.

The first paper that deals specifically with the cubic surface is one by L. Mossbrugger,† “Untersuchungen über die geometrische Bedeutung der constanten Coefficienten in den allgemeinen Gleichungen der Flächen des zweiten und dritten Grades,” which appeared in the first volume of the *Archiv der Mathematik und Physik*, 1841.

The theory of straight lines upon a cubic surface was first studied in a correspondence by the English mathematicians Salmon and Cayley and the results were published, *Camb. and Dublin Math. Journal*, Vol. IV. (1849), pp. 118-132 (Cayley), pp. 252-260 (Salmon). The observation that a definite number of straight lines must lie on the surface is initially due to Cayley, whereas the determination of that number was first made by Salmon.‡

*Bull. Am. Math. Soc. Vol. III. (1897) pp. 136-146.

†J. E. Hill, l. c.

‡Salmon, *Geom. of Three Dimensions*, 4th edition, §680, note. Cf. also Cayley, *Coll. Math. Papers*, Vol. I., note p. 589.

The basis for a purely geometric theory of cubic surfaces was laid by Steiner* in a short but extremely fruitful memoir, containing many theorems, given either wholly without proof or with but the barest indication of the method of derivation—a habit of "*ce celebre sphinx*," as he has been styled by Cremona.

On account of the "complicated and many-sided symmetry" among the relations between the twenty-seven lines upon the cubic surface, great difficulty was at first experienced in obtaining any adequate conception of the complete configuration. The notation first given by Cayley was obtained by starting from some arrangement that was not unique, but one of a system of several like arrangements, yet it was so complicated as scarcely to be considered as at all putting in evidence the relations of the lines and triple tangent planes. Hart gave a very elegant and symmetrical notation for the lines and planes, an account of which is to be found in the original paper of Salmon,† who also gave a notation of limited usefulness. Schläfli‡ it was who invented the notation that might be called epoch-making—that of the double-six,|| which has remained unimproved upon up to the present time. This notation is one out of a possible thirty-six of like character among the twenty-seven lines. Taylor† has recently given a notation for the lines independent of any particular, initial choice but this cannot be regarded as an improvement upon the Schläfli notation.

The foundations for subsequent analytic investigations concerning the twenty-seven lines were laid, as has been seen, by Cayley and Salmon, and in fact Sylvester§ once said in

*"Ueber die Flächen dritten Grades," read to the Berlin Academy, 31st January, 1856; Orelle, Bd. LIII.

‡Infra, §4.

†Quarterly Journal, Vol. 2 (1858), pp. 55-65, 110-120.

||For the history of the double-six theorem see infra, §6.

†Philos. Trans. Royal Soc. Vol. CLXXXV. (1894), part I. (A), pp. 37-69,

§Proc. London Math. Soc. Vol. 2, p. 155.

his habitually florid style, "Surely with as good reason as had Archimedes to have the cylinder, cone and sphere engraved on his tombstone might our distinguished countrymen leave testamentary directions for the cubic eikosiheptagram to be engraved on theirs."

The first significant papers on cubic surfaces from the synthetic standpoint, after Steiner's memoir above mentioned, were by Cremona and Rudolf Sturm. These were two of the four papers submitted in competition for the prize offered by Steiner through the Royal Academy of Sciences of Berlin in 1864, which was divided between Cremona and Sturm on Leibniz Day, 1866. The beauty and simplicity of many of the methods employed in these papers eminently justified Steiner's original remark, "Es ist daraus zu sehen, dass diese Flächen fortan fast eben so leicht und einlässlich zu behandeln sind, als bisher die Fläche zweiten Grades." Cremona's "*Mémoire de géométrie pure sur les surfaces du troisième ordre*" is found in Crelle's Journal,* whereas Sturm's paper was subsequently expanded into a treatise.†

Schläfli (*l. c.*) first considered a division of the general surface of the third order into species, in regard to the reality of the twenty-seven lines, but he then contented himself with a mere survey of the problem. This was in 1858. But in 1862, F. August‡ gave a rather extended investigation of the subject. In 1863 appeared a valuable memoir by Schläfli,§ treating the subject in great detail. He also, as the title indicates, makes there a division of the surface into types, depending upon the nature of the singularities,—a classifica-

*Vol. LXVIII. (1868), pp. 1-188.

†"Synthetische Untersuchungen über Flächen dritter Ordnung." B. G. Teubner, Leipzig, 1867.

‡"Disquisitiones de superficiebus tertii ordinis," Dissert. inaug. Berolini, 1862.

§"On the Distribution of Surfaces of the Third Order into Species, in reference to the presence or absence of Singular Points and the reality of their Lines," Philos. Trans. Vol. CLIII. (1868), pp. 192-241.

tion used by Cayley* in his "Memoir on Cubic Surfaces."

If Cayley and Salmon had wished to follow Sylvester's advice and to insert a clause in their wills, directing that a figure of the cubic eikosiheptagram be engraved upon their monuments, they would have had no certainty of the correct fulfilment of their directions until the year 1869 when Dr. Christian Wiener† made a model of a cubic surface, showing twenty-seven real lines lying upon it. This achievement of Dr. Wiener, Sylvester‡ once remarked, is one of the discoveries "which must forever make 1869 stand out in the Fasti of Science." Since that time, there have been constructed models of all the various types of the cubic surface, showing the lines lying entirely upon them. The list of those who have written on the mechanical construction of the configurations of the lines upon a cubic surface and the general subject of the collocation of the lines upon the surface includes the names of Salmon, Sylvester, Cayley, P. Frost, Zeuthen and Blythe.||

The configuration of the twenty-seven lines is not only of the highest interest *per se*, but also on account of its close association and relation to other remarkable configurations. It was also in the year 1869 that Geiser§ showed the mutual interdependence of the configurations of the twenty-eight bitangents to a plane quartic curve and the twenty-seven lines upon a cubic surface, and the method of derivation of each from the other. By making use of Geiser's results, Zeuthen† obtained a new demonstration of the theorems of Schläfli‡ upon the reality of the lines and tripletangent planes

*Philos. Trans. Royal Soc. London, Vol. CLIX. (1869), pp. 231-336.

‡Of. Cayley, Trans. Camb. Philos. Soc. Vol. XII. Part I (1873), pp. 366-388, where a description of the model is given.

‡Proc. London Math. Soc. Vol. 3, p. 155.

||Of. *infra*, §§18-21.

§Math. Ann. Bd. I. (1869), pp. 139-188.

†Math. Ann. Bd. 7 (1874), pp. 410-433.

‡Quarterly Journal, Vol. 2, (1858); Philos. Trans. Vol. 153 (1868),

of a cubic surface. Indeed, it is feasible to derive the properties of one configuration from the known properties of the other.*

In 1877 Cremona† first showed that the Pascalian configuration might be derived from the configuration of the twenty-one lines upon the surface of the third degree with one conical point (Species II., Cayley's enumeration) by projection from the conical point.

The theory of *varieties* of the third order, that is to say, curved geometric forms of three dimensions contained in a space of four dimensions, has been the subject of a profound memoir by Corrado Segre.‡ The depth of this paper is evinced by the fact that a large proportion of the propositions upon the plane quartic and its bitangents, Pascal's theorem, the cubic surface and its twenty-seven straight lines, Kummer's surface and its configuration of sixteen singular points and planes, and on the connection between these figures are derivable from propositions relating to Segre's cubic variety, and the figure of six points or spaces from which it springs.† Other investigators on this beautiful and important locus in space of four dimensions and some of its consequences are Castelnuovo and Richmond.§

The problem of the twenty-seven lines is full of interest from the group theoretic standpoint. In 1869 Camille Jordan|| first proved that the group of the problem of the trisection of hyperelliptic functions of the first order is isomorphic with

*Orelle's Journal, Vol. 122 (1900), pp. 209-226.

‡Reale Accademia dei Lincei, Anno CCLXXIV. (1876-77). Roma. Also of. infra, §§47, 48.

†Atti d. R. Accad. di Scienze di Torino, Vol. XXII. (1887), pp. 547-557. Memorie d. R. Accad. di Scienze di Torino, Series 2, Vol. XXXIX. (1889), pp. 8-48.

‡Richmond, Quarterly Journal, Vol. XXXIV. No. 2 (1902), pp. 117-154.

§Of. Richmond l. c. for references.

||Comptes Rendus, 1869. Of. also Traite des Substitutions, p. 216 et seq., p. 365 et seq.

the group of the equation of the twenty-seventh degree, on which the twenty-seven lines of the general surface of the third degree depend. Felix Klein† in 1887 sketched the effective reduction of the one problem to the other. In 1887-9 Maschke‡ in a series of papers set up the complete form-system of a quaternary group of 51840 substitutions, and in 1893 Burkhardt,|| on the basis of Klein's paper above mentioned, these papers of Maschke and one by Witting,§ carried out the work sketched by Klein—the reduction of one problem to the other.

Since Jordan's first paper appeared in 1869, a number of writers have studied the Galois group of the equation of the twenty-seven lines. Dickson** has led in this investigation, publishing a number of papers on the subject. Other writers on the same subject are Kühnen,†† Weber,‡‡ Cartan and, more recently, Kasner. This last paper is in close contact with the investigations of Moore and Slaughter on the cross-ratio group of Cremona transformations.

INTRODUCTION.

The problem of the twenty-seven lines upon a cubic surface is of such scope and extent and is allied to so many other problems of importance that to give a *resume* of all that has

†Extrait d'une lettre adressée à M. O. Jordan, *Journal de Liouville*, series 4, tome IV. (1888), p. 169 et seq.

‡*Math. Ann.* Bd. XXX. (1887), pp. 496-515; *Gött. Nach.* (1888), pp. 76-86; *Math. Ann.* Bd. 33, (1889), pp. 317-344.

||*Math. Ann.* Bd. 41 (1893), pp. 309-343.

§*Math. Ann.* Bd. 29 (1887).

***Trans. Am. Math. Soc.* Vol. 2 (1901), pp. 137-188; *Quarterly Journal* Vol. 33 (1901), pp. 145-178; *Bulletin Am. Math. Soc.* Vol. 8 (1901), p. 68 et seq.; *Linear Groups* Ch. XIV. pp. 308-307.

††"Über die Galois'sche Gruppe der Gleichung 27 Grades, von welcher die Geraden auf der allgemeinen Fläche dritter Ordnung abhängen," Diss. Marburg, 1888.

‡‡*Math. Ann.* Bd. XXIII., pp. 469-508.

been done upon the subject would enlarge the present paper into a book. It was found impossible to cover even the geometrical phases of the problem, in their extension in particular to the cognate problem of the forty-five triple tangent planes, although the two subjects go hand in hand. In this memoir, however, is given a general survey of the problem of the twenty-seven lines, from the geometric standpoint, with special attention to salient features, i. e., the concept of trihedral pairs, the configuration of the double-six, the solution of the problem of constructing models of a double-six and of the configurations of the lines upon the twenty-one types of the cubic surface, the derivation of the Pascalian configuration from that of the lines upon the cubic surface with one conical point, and certain allied problems.

In §§ 1-4 are given certain preliminary theorems concerning the existence and number of the twenty-seven lines and forty-five planes for the general cubic surface, and upon the first notation employed. In §§ 5, 6 and 7 are given an account of Schläfli's notation, a history of the double-six theorem and an analytic proof of it, independent of cubic surfaces; in §8 follow certain interesting results on the anharmonic ratios of the configurations. In §9 appear two conditions that five lines lie upon a cubic surface and in §10 is the description of the formation, and the tabulation of the thirty-six double-sixes. In §11 occur certain auxiliary theorems for special features of the general configuration of the twenty-seven lines.

In §12 are given the definition and number of trihedral pairs, and in §13 the actual formation of the tables of the 120 forms. In §14 these are grouped together in such a way (sets of three) as to determine in forty ways all the twenty-seven lines.

In §16 is given a discussion of a special form of the general equation of the cubic surface and the determination of the equations of the forty-five triple tangent planes.

In §§18 and 19 the methods for the construction of a model

of a double-six are discussed and a practical method is there given in detail.

In §§20 to 45 the general problem of constructing thread or wire models of the configurations of the lines upon all twenty-one types of the cubic surface is fully considered, and a complete solution of the problem given.

In §46 is given a discussion of the derivation of the Brianchon configuration from two spatial point triads, and in §§47-8 the discussion of the derivation of the Pascalian configuration from that of the straight lines upon the second species of the cubic surface (Cayley's enumeration) and a graphic representation of the same.

Finally, in §49 appears a theorem on the number of cubic surfaces with one conical point passing through the lines of mutual intersection of two triheders.

CHAPTER I.

PRELIMINARY THEOREMS.

§1 *Existence of Straight Lines upon a Cubic Surface.*

In order to find the conditions that any straight line, whose equations are

$$\frac{x - x_0}{\lambda} = \frac{y - y_0}{\mu} = \frac{z - z_0}{\nu} = r,$$

lie entirely upon a surface, we substitute $x = x_0 + \lambda r$, $y = y_0 + \mu r$, $z = z_0 + \nu r$ in the equation of the surface, arrange the terms of the resulting equation according to powers of r and then set all the coefficients of r equal to zero,

since the equation in r must be identically satisfied, i. e., for all values of r . Since in this case the equation of the surface is of the third degree, there result four conditions. But the equations of a straight line involve four disposable constants, and, as the number of conditions to be fulfilled is exactly equal to the number of disposable constants in the equations of the straight line, it follows that every surface of the third order must contain a finite number of straight lines, real or imaginary, lying entirely upon it.

§2. *Number of Straight Lines upon a Cubic Surface.*

Suppose we pass a plane π through a point P outside the surface and through a straight line l lying upon the surface. Then π meets the surface in the line l , and a conic C besides (since the curve of intersection is a degenerate cubic), i. e. meets the surface in a section having two double-points and therefore by definition is a double-tangent plane. These double-tangent planes π to the cubic surface are also double-tangent planes to the tangent cone, vertex P . Now since to every plane π corresponds one straight line l lying entirely on the surface and as there are twenty-seven* ($n = 3$) double-tangent planes to the tangent cone, vertex P , therefore there are twenty-seven straight lines l on the cubic surface.†

§3. *Triple Tangent Planes.*

By properly determining the plane passed through any straight line l upon the cubic surface, the conic C (§2) will

*Salmon, *Geom. of Three Dimensions*, 4th edition, §286 gives

$$\frac{n}{2}(n-1)(n-2)(n^2-n^3+n-12)$$

as the number of double-tangent planes, drawn through a point P to a surface of the n th degree.

†For other proofs compare R. Sturm, *Flächen dritter Ordnung*, Kap. 2, §20, and Cayley, *Coll. Math. Papers*, Vol. I., No. 76 (445-456).

degenerate into a pair of straight lines. Here the plane intersects the surface in three intersecting straight lines (a degenerate curve of the third order having three double points) and the points of intersection of the lines taken in pairs are the points of contact of the plane with the surface. Now through each of the three lines in the plane there may be drawn, besides the given plane, four triple tangent planes. For these twelve new planes give rise to twenty-four new lines upon the surface, making up with the former three lines, twenty-seven lines upon the surface. It follows that every straight line on the surface is met by ten others.

If all the twenty-seven lines intersect in pairs, there would be 351 points of intersection. But since each line is met by ten other lines, there remain 16 lines by which it is not met and therefore there are $\frac{27 \times 16}{2} = 216$ pairs of lines that do not intersect. Consequently there are 135 points of intersection.

Since these 135 points, by threes, determined the triple tangent planes, there are 45 triple tangent planes.

Consider the three lines a , b , and c say, the complete intersection of the triple tangent plane π with the surface. Then every other line l upon the surface must meet the triple tangent plane in a point upon one (a say) of the three lines a , b , and c , and accordingly must lie in a plane π_1 , passing through a . Since the intersection of the surface by the plane π_1 must be a cubic curve, which is already composed of two straight lines, the plane π_1 meets the surface in a third straight line l' , and therefore must be a triple tangent plane. Hence l' must be one of the given 27 lines and it appears that there can be but 27 lines upon a cubic surface.

§4. *Salmon's Notation for the Twenty-Seven Lines.**

Lemma. *The general equation of the cubic surface may be*

*Camb. and Dublin Math. Journal (1849), Vol. IV., pp. 252-260.

reduced to the canonical form $uvw - \xi\eta\zeta = 0$, where $u, v, w, \xi, \eta, \zeta$ are linear polynomes.

The number of independent constants in the general equation of the third degree is $19\left[\frac{n(n^2 + 6n + 11)}{6}, \text{ for } n = 3\right]$.

Since the linear polynomes $u, v, w, \xi, \eta, \zeta$ contain 18 ratios of coefficients and there is one other constant factor implicitly contained in one of the products $uvw, \xi\eta\zeta$, therefore the forms $uvw - \xi\eta\zeta = 0$ contains 19 constants and is one into which the general equation of a cubic surface may be thrown.

It will appear later (§15) from geometrical considerations that the problem to reduce the base cubic to the form $uvw - \xi\eta\zeta = 0$ is soluble in 120 different ways.

NOTATION. Consider the canonical form of the surface of the third degree $ace - bdf = 0$, where a, b, c, d, e, f are linear polynomes. By inspection it is patent that this surface contains the nine lines $ab, ad, af, cb, cd, cf, eb, ed, ef$ where ab , for example, represents the line of intersection of the planes $a = 0, b = 0$. If we suppose $a = \mu b$ to be the equation of one of the triple tangent planes through the intersection of the planes a and b , the plane $a = \mu b$ meets the surface in the same lines in which it meets the hyperboloid $\mu ce - df = 0$, that is, the two lines in the plane are generating lines of different species, and consequently one of them meets the pair of lines cd and ef , and the other of them meets the pair of lines cf and ed . Let us now denote each of the remaining eighteen lines by the three lines which it meets, the line meeting ab, cd and ef being denoted by the symbol $ab \cdot cd \cdot ef$. Since μ has three values, there are three lines that meet ab, cd, ef . Applying the same reasoning to the planes through bc and ca , we employ the following symbolism for the twenty-seven lines $ab, ad, \dots, ef$; $(ab \cdot cd \cdot ef)_1, (ad \cdot cf \cdot eb)_1, (af \cdot cb \cdot ed)_1, (ab \cdot cf \cdot ed)_1, (ad \cdot cb \cdot ef)_1, (af \cdot cd \cdot eb)_1$, where $\iota = 1, 2, 3$.

Unfortunately our information as to how these suffixes are to be applied is inadequate and certain postulates have to be made as to how the intersections occur.* This notation of Salmon was the first one that was given for the twenty-seven lines, and was superseded by a very superior one to be explained in the next article.

**Of. Salmon, l. c.*

MOLECULAR ATTRACTION, IV., ON BIOT'S FORMULA FOR VAPOR PRESSURE AND SOME RELATIONS AT THE CRITICAL TEMPERATURE.¹

J. E. MILLS.

THE $\frac{\partial P}{\partial T}$ OF A LIQUID.

In a preceding paper² we examined the following equation, which had been proposed on theoretical grounds by Mr. H. Crompton,

$$[1] \quad L = 2 \int_v^V p \delta v = 2RT \log_e \frac{d}{D} = \frac{9.154}{m} T \log \frac{d}{D} \text{ cal.}$$

(L is heat of vaporization, v and V denote volume of liquid and vapor, d and D the density of liquid and vapor, p is pressure, T is temperature, m is molecular weight, R is the constant of the gas equation, $PV = RT$.)

It was there shown that this equation gives at low temperatures where the pressure is small, results for the heat of vaporization that are invariably and usually very considerably too large. But at the higher temperatures examined, that is as the critical temperature is approached, the results given by the equation appeared to be correct. The evidence there given as to the correctness of this equation at high temperatures was very considerable and justified further use of the equation. Therefore in this paper we combined the usual thermodynamical equation for calculation of the heat of vaporization,

¹Reprinted, with omission of a Table, from *Jour. Phys. Chem.*, 9, p. 402, 1905.

²*Jour. Phys. Chem.* 8, 598 (1904).

$$[2] \quad L = \frac{T}{J} (V - v) \frac{\delta P}{\delta T} = .031833 T (V - v) \frac{\delta P}{\delta T} \text{ cal.}$$

with the equation of Crompton given above, and obtained equation 15 of that paper, viz.:

$$[3] \quad \frac{\delta P}{\delta T} = \frac{287500}{m} \frac{\log \frac{V}{v}}{V - v}$$

We there showed that the limit approached by this equation as the critical temperature was approached and V approached v in value, was,

$$[4] \quad \frac{\delta P}{\delta T} = \frac{124860}{mV}.$$

We at that time overlooked the fact that this equation 4 could be expressed in the very simple form,

$$[5] \quad \frac{\delta P}{\delta T} = \frac{2R}{V}.$$

Here V is the critical volume and R is the usual gas constant, and we have the striking conclusion that *at the critical temperature the $\frac{\delta P}{\delta T}$ of the liquid (vapor) is exactly twice what it would be for that substance as a perfect gas occupying the same volume.* Expressed in this form the bearing of equation 3, or its limiting forms, on the kinetic relations of a liquid and its vapor, assumes more importance and justifies a closer study.

Accordingly by means of equation 4, we calculated, and give in Table 1, the values of the $\frac{\delta P}{\delta T}$ at the critical temperature for twenty substances. The critical data used is that given by Dr. Young¹. This data is more correct than that given in earlier papers. (We would here note that in the third paper on Molecular Attraction² we overlooked this corrected data, but have since repeated the calculations there given

¹Phil. Mag., [5], 50, 291 (1900).

²Jour. Phys. Chem., 8, 598, (1904).

using the corrected data and find no material change in the results or conclusions there expressed.)

For comparison with these values the $\frac{\delta P}{\delta T}$ can be calculated from any equation connecting vapor pressure and temperature. Of the numerous equations that have been proposed the one usually known as Biot's has proved by far the most serviceable. It takes the form,

$$[6] \quad \text{Log } P = a + b \cdot \alpha^t + c \cdot \beta^t.$$

By differentiating and changing to Napierian logarithms we get,

$$[7] \quad \frac{\delta P}{\delta T} = 5.3019 P(b \cdot \log \alpha \cdot \alpha^t + c \cdot \log \beta \cdot \beta^t).$$

Since we had previously used Biot's formula for calculating heats of vaporization more directly, we found it easier to throw equation 7 into the form,

$$[8] \quad \frac{\delta P}{\delta T} = .031414 P A,$$

where, $A = 168.775 (b \cdot \log \alpha \cdot \alpha^t + c \log \beta \cdot \beta^t)$. The constants for this equation have already been given¹ for all of the substances examined except those noted below.

Ethyl oxide. $A = \text{antilog } (\bar{1}.9882227 - .00172541 t)$
 $+ \text{antilog } (\bar{1}.7399799 - .00869664 t),$

$t = t^\circ \text{ C.}$

Benzene. $A = \text{antilog } (\bar{1}.4256719 + .0001302029 t)$
 $+ \text{antilog } (0.1799122 - .00410411 t),$

$t = t^\circ \text{ C.}$

Methyl alcohol. $A = \text{antilog } (\bar{1}.5561254 - .00011584 t)$
 $+ \text{antilog } (.2.51667 - .00400204 t),$

$t = t^\circ \text{ C.}$

Ethyl alcohol. $A = \text{antilog } (\bar{2}.3965216 + .003377538 t)$
 $+ \text{antilog } (0.3342413 - .00317576 t),$

$t = t^\circ \text{ C.}$

¹Jour. Phys. Chem., 8, 888 (1904).

Propyl alcohol. $A = \text{antilog } (2.8340346 + .001641423 t)$
 $+ \text{antilog } (.03135244 - .00342975 t),$
 $t = {}^{\circ}\text{C} - 20.$

The constants for ethyl formate and methyl acetate were kindly sent me by Dr. Young (work yet unpublished) and the constants for methyl formate I have calculated and will publish later.

The values of the $\frac{\delta P}{\delta T}$ at the critical temperature as obtained from these Biot equations are shown in Table 1.

Of the twenty substances compared in Table 1 it will be seen that the $\frac{\delta P}{\delta T}$ from equation 4 has a higher value than the $\frac{\delta P}{\delta T}$ calculated from Biot's formula in all cases except di-isobutyl, normal octane, and ethyl alcohol. The difference is usually very marked.

In work done upon an equation of the form, $P = bT - a$, Ramsay and Young¹ made a study of the $\frac{\delta P}{\delta T}$ of ether at constant volume, Young², later, a similar study for isopentane, and Rose-Innes and Young³ correspondingly for normal pentane. At the critical volume the values of the $\frac{\delta P}{\delta T}$ obtained at constant volume becomes identical with the value of the $\frac{\delta P}{\delta T}$ denoting the increase in vapor pressure of the liquid. Therefore it is possible in these three cases by comparison with the values of the $\frac{\delta P}{\delta T}$ obtained in the above papers to determine whether the values of the $\frac{\delta P}{\delta T}$ calculated from Biot's

¹Phil. Mag. [5], 23, 435, (1887).

²Ibid, [5], 33, 569, (1894).

³Ibid. [5], 47, 353 (1899).

TABLE 1.

SUBSTANCE	Critical Temperature	$\frac{P}{T}$ from Equation 4	$\frac{P}{T}$ from Biot	Δ	Λ
Ethyl oxide.....	194.45°C	441.9	391.6	50.3	.46068
Di-isopropyl.....	227.85	849.6	321.0	28.6	.43796
Di-isobutyl.....	276.8	268.8	261.6	-2.8	.44672
Isopentane.....	187.8	405.7	367.8	37.9	.46832
Normal pentane.....	197.2	402.8	364.8	37.5	.46331
Normal hexane.....	234.8	389.9	315.9	24.0	.44826
Normal heptane.....	266.85	291.9	286.9	5.0	.44782
Normal octane.....	296.2	254.5	256.8	-2.3	.43647
Benzene.....	268.5	487.0	445.4	41.6	.38961
Hexamethylene.....	279.25	406.0	376.0	30.0	.39588
Fluo-benzene.....	236.55	480.1	430.7	29.4	.40428
Carbon tetrachloride.....	283.15	452.7	416.7	36.0	.38808
Stannic chloride.....	318.7	355.2	332.5	22.7	.37689
Methyl formate.....	314.0	725.6	619.2	106.4	.46872
Ethyl formate.....	285.8	545.0	479.7	65.3	.48091
Methyl acetate.....	232.7	548.8	502.8	46.0	.45454
Methyl alcohol.....	240.0	1061.1	971.1	90.0	.51729
Ethyl alcohol.....	243.1	747.0	796.7	-49.7	.53998
Propyl alcohol.....	262.7	568.8	562.4	5.9	.47181
Acetic acid.....	321.65	729.2	574.6	154.6	.42966

formula or those obtained from equation 4 are correct. The result is shown below, the value of the $\frac{\delta P}{\delta T}$ at the exact critical volume having been obtained from the above mentioned papers by interpolation and entered in the column marked "Observed".

Substance	Volume	From Biot	Equ'tion 4	Observed
Ether	3.815	391.6	441.9	436
Isopentane	4.268	367.8	405.7	401 to 411
Normal pentane	3.305	364.8	402.3	406.7

In every case the values accord to within the limit of experimental error with the values derived from Biot's equation. (It is not possible to extend the comparison to the alcohols and acetic acid studied by the observers above mentioned, for these liquids are associated and equation 4 depending on the molecular weight, could not give correct results.

ON BIOT'S FORMULA FOR VAPOR PRESSURE.

It seemed to us reasonable to conclude from the above comparison that the ratios of the $\frac{\delta P}{\delta T}$ calculated from equation 4 at the critical temperature and shown in Table 1 were the correct values and that the values obtained from Biot's formula were in error. Fortunately we had a means of verifying this conclusion directly.

If the vapor pressure curve be plotted, the $\frac{\delta P}{\delta T}$ is the tangent to the curve. Assuming that Biot's formula does correctly represent the vapor pressures until the critical temperature is approached (an assumption justified by a very careful examination of the curves over the entire range of temperature) it is evident that if the $\frac{\delta P}{\delta T}$ calculated from Biot's form-

ula then becomes too low it must be because the vapor pressure curve as calculated from Biot's formula is below the true vapor pressure curve. We accordingly subtracted the observed vapor pressures from the calculated in the immediate neighborhood of the critical temperature. (These results are shown in detail in Table 2, Jour. Phys. Chem. 9, p. 402 [1905]). In every case except normal octane, stannic chloride, and the associated substances (methyl alcohol, ethyl alcohol, and acetic acid), the calculated minus the observed vapor pressures does give negative differences at the highest temperature compared (usually the critical temperature itself). With regard to these five exceptions, the associated substances cannot give exactly correct results by the use of equation 4 and their evidence does not therefore bear upon that equation. Normal octane and stannic chloride are the only substances whose divergence can be considered as evidence against the conclusion above derived and it is sufficient to point out in explanation a remark made by Dr. Young¹ when the vapor pressures of normal octane were published. He there states that the observed values of the vapor pressure above 280° C for *normal octane, stannic chloride, and acetic acid*, are probably *too low* owing to an error in the temperature scale, i. e., in the boiling points of the liquids used as a heating jacket.

A close examination of the observed and calculated vapor pressure curves reveals the fact that no matter how the constants for Biot's formula be altered they cannot exactly represent the true vapor pressures in the neighborhood of the critical temperature. The deviation is very slight, usually negligible when the vapor pressure is considered, because the proportional error is very small. But when the $\frac{\delta P}{\delta T}$ is considered the proportional error is very large.

Since Biot's formula was empirical and in the immediate neighborhood of the critical temperature was forced to fit a curve it could not exactly follow it usually happens that the

¹ Jour. Chem. Soc., 77, 1147 (1900).

TABLE 2.

SUBSTANCE	Temperature	Old μ'	New μ'	Mean μ'	Critical Temperature	μ' From Equation 12	$\frac{P V_m}{T}$
Ethyl oxide	198	90.7	102.0	104.4	194.4	102.1	16860
Di-isopropyl	225	92.0	96.8	98.1	227.4	96.5	16660
Di-isobutyl	274	86.4	82.8	86.8	276.8	80.7	16870
Isopentane	187.4	99.8	107.0	105.4	187.8	107.0	16710
Normal pentane	197	98.8	109.9	109.9	197.2	109.4	16570
Normal hexane	234	94.2	99.5	102.85	234.8	99.2	16290
Normal heptane	266.5	90.8	91.0	96.75	266.9	90.8	16170
Normal octane	290	91.0	84.8	98.0	296.2	84.2	16140
Benzene	280	107.8	111.2	109.5	288.5	110.5	16610
Hexamethylene	279	96.1	104.7	108.6	280.0	104.5	16820
Fluo-benzene	280	84.7	85.75	85.6	286.55	85.2	16440
Chlor-benzene .....	.....	.....	.....	81.2	360.0	81.5	16490
Brom-benzene .....	.....	.....	.....	56.1	397.0	56.8	16890
Iodo-benzene .....	.....	.....	.....	44.4	448.0	48.8	16500
Carbon tetrachloride	280	48.9	45.5	44.1	288.15	45.8	16940
Stannic chloride	280	22.15	26.96	26.04	318.7	25.87	16680
Methyl formate	218.5	101.2	120.1	121.5	214.0	119.8	15910
Ethyl formate	234	94.0	104.4	107.2	235.8	106.9	16040
Methyl acetate	238	96.6	108.8	109.5	238.7	103.6	15800
Methyl alcohol	238.5	259.4	264.8	305.0	240.0	263.4	13705
Ethyl alcohol	242.5	197.2	178.9	241.2	248.1	179.9	15495
Propyl alcohol	260	157.0	144.6	199.3	263.7	143.7	15590
Acetic acid	330	116.4	150.6	.....	321.6	150.7	12502

curve of observed vapor pressures cuts the curve of calculated vapor pressures in the neighborhood of the critical temperature, the observed vapor pressure curve having, of course, the steeper trend. This is at once evident by the change from positive to negative values of the differences between the calculated and observed vapor pressures.

We would here point out the great accuracy of these measurements made by Drs. Ramsay and Young and by Dr. Young and his co-workers. The conclusion that the calculated minus the observed vapor pressure should be negative near the critical temperature was wholly theoretical on our part. That we should be able at once to verify this conclusion from the measurements when the differences were so small as to have been laid by the observers themselves on the errors of measurement (the regularity of the differences having escaped observation) speaks for itself as to their accuracy and skill. The observed and calculated vapor pressure lines are almost indistinguishable even at the critical temperature and when drawn to a large scale.

In order to show that equation 4, or the more general form equation 3, does give results in accord with Biot's formula at points considerably below the critical temperature we have published in Table 2, Jour. Phys. Chem. 9, p. 408 (1905), the values of the $\frac{\delta P}{\delta T}$ calculated from both formulas at intervals for some 50° C below the critical temperature. We have already pointed out that equation 3 itself becomes inaccurate at yet lower temperatures.

CORRECT VALUES FOR μ' NEAR THE CRITICAL TEMPERATURE.

Since equation 3 enables us to obtain in the neighborhood of the critical temperature more nearly correct values for the $\frac{\delta P}{\delta T}$ than we had been able to obtain in previous papers when

working with Biot's formula we concluded to use these values and test more thoroughly the equation,

$$[9] \quad \frac{L - E_1}{\sqrt[3]{d} - \sqrt[3]{D}} = \text{constant} = \mu'.$$

discussed in previous papers¹. If the value of the $\frac{\delta P}{\delta T}$ from equation 3 be substituted in the thermodynamical equation 2, the values of the heat of vaporization so calculated are the same as those obtained from equation 1. Therefore using these values and substituting them in equation 9 we obtain the corrected values for the constant. The results so obtained at those points nearest the critical temperature are given in Table 2 under the heading "New". For comparison we give under heading "Old" the values that we had previously obtained for μ' at this same temperature when using the $\frac{\delta P}{\delta T}$

obtained from Biot's formula in calculating the heats of vaporization thermodynamically. Also we give, under the heading "Mean", the average value of the constant previously adopted. Agreement is not of course to be expected for the four associated substances last shown in the table. For the other substances there is little question but that the constants so obtained agree with the mean values to within the limit of experimental error except in the cases of di-isobutyl, normal heptane, normal octane, and methyl acetate. We are unable to explain the smaller values obtained from these four substances, but the proof that equation 9 does hold as near the critical temperature as it is possible for measurements to be made is now complete for ethyl oxide, di-isopropyl, isopentane, normal pentane, normal hexane, benzene, hexamethylene, fluo-benzene, carbon tetrachloride, stannic chloride, methyl formate, and ethyl formate.

¹Jour. Phys. Chem., April, 1902; June, 1904; Dec., 1904.

THE VALUE OF μ' AT THE CRITICAL TEMPERATURE.

It is possible to extend this proof quite to the critical temperature itself. Substituting in equation 9 the value of L given by the thermodynamical equation 2, and the value of $E_c = .03183 P (V - v)$, we have

$$[10] \quad \frac{.031833 \left(T \frac{\delta P}{\delta T} - P \right) (V - v)}{\cancel{V}^{\delta} - \cancel{v}^{\delta}} = \mu',$$

and obtaining the limit of this equation as V approaches v in value we have for the equation at the critical temperature, where $V = v$, the form

$$[11] \quad .0955 V \left(T \frac{\delta P}{\delta T} - P \right) = \mu'.$$

As we have shown the most correct value for the $\frac{\delta P}{\delta T}$ available at this temperature is that given by equation 4 and substituting this value in the equation we get,

$$[12] \quad \mu' = V \left(\frac{11.924 T}{m} - .0955 P V \right).$$

This equation is the same as equation 17 of the third paper¹. Here V , T , and P , are the critical volume, temperature, and pressure respectively, and m is the molecular weight of the substance under consideration. The equation is interesting because it gives a method for calculating the constant of molecular attraction, μ' , in terms of the critical constants and the molecular weight of the substance. Since the molecular weight enters into the equation it evidently cannot be applied to associated substances. Again using the critical data, already referred to, given by Young, the values obtained from this equation are shown in Table 2 above. Except for di-isobutyl, normal heptane, normal octane, methyl acetate,

¹Jour. Phys. Chem., Dec., 1904.

and to a less degree for ethyl formate, the agreement with the mean values of μ' is excellent and we may therefore regard the truth of equation 9 as having been established at the critical temperature itself for fifteen of the nineteen substances under consideration. (Ethyl formate decomposes slightly at the higher temperatures which is sufficient to account for the divergence, three per cent., there observed.) We have already shown that normal heptane and normal octane give constant values for μ' in equation 9 over a range of more than 200° C in temperature. We have unpublished results showing the same to be true for methyl acetate. Diisobutyl did give a variation of several per cent. at low temperatures, a divergence that we think was sufficiently explained¹. It would seem probable therefore that the divergences shown by these four substances at the critical temperature must be due to some change or decomposition taking place in the substance at that temperature and that equation 9 is applicable for all normal substances quite up to the critical temperature.

RATIO OF THE THEORETICAL TO THE ACTUAL CRITICAL DENSITY.

In a preceding paper² we showed that the molecular attraction at unit distance, μ , was equal to $c\mu'\sqrt[3]{m}$. Therefore we have from equation 12,

$$[13] \quad \mu = c\sqrt[3]{mV} \left(\frac{11.924 T}{m} - .04955 P V \right).$$

In the same paper on the assumption that the critical temperature was the point where the kinetic energy of the molecules was just balanced by the molecular attraction we derived equation 24 of that paper, viz.:

¹Jour Phys. Chem., 8, 595 (1904).

²Jour. Phys. Chem., 8, 630 (1904).

$$[14] \quad \mu = c \frac{T}{m} \sqrt{\frac{m}{d}}.$$

where T is the critical temperature and d is the critical density. We can now combine this value of μ with the value of μ given in equation 13 and obtain,

$$[15] \quad c \frac{T}{m} \sqrt{\frac{m}{d}} = \sqrt{\frac{m}{V}} \left(\frac{11.924 T}{m} - .04955 P V \right),$$

whence,

$$[16] \quad \frac{P V m}{T} = \text{constant}.$$

We show the values of $\frac{P V m}{T}$ in Table 2 and it will be seen that hexamethylene and carbon tetrachloride alone (the associated substances being excepted) give a value more than three per cent. from the average value 16293.

$\frac{.0416014 P m}{T}$ is the theoretical critical density and equation

16 is really the ratio of the theoretical, D_o , to the actual critical density, d_o , and can take the form,

$$[17] \quad \frac{D_o}{d_o} = \text{constant}.$$

The relation in this form has been fully discussed by Dr. Young¹. It here appears as a necessary consequence of the ideas that we have advanced though we did not foresee that such would be the case, and hence are justified in considering the deduction of this relation as further evidence that those fundamental ideas upon which this series of papers is based are correct.

It may seem unusual that we should have been able to derive two different equations for μ (equations 13 and 14) in terms of the critical constants. This is due to the fact that the critical temperature besides possessing the property that the molecular attraction just balances the kinetic energy of the molecules—the relation upon which equation 14 is based

¹Phil. Mag., [5], 50, 291 (1900).

—can also be viewed as the boiling point and from this point of view permits the deduction of equation 13. We hope shortly to complete a paper applying these ideas of molecular attraction more fully to the boiling point.

We should also point out that by combining equation 11 with equation 14, we get,

$$[18] \quad \frac{T}{m} = c V \left(T \frac{\partial P}{\partial T} - P \right),$$

where c is a constant. This equation can be solved so as to give any one of the variables at the critical temperature in terms of the others and the molecular weight. It is not feasible now to further examine this equation, since the only correct values for the $\frac{\partial P}{\partial T}$ are obtained from equation 4 and this at once reduces the equation to the form of equation 16.

Dr. Young has shown that the average constant of equation 17 is $\frac{1}{3.827}$. Since the theoretical critical pressure is therefore 3.827 times the actual critical pressure it follows from the gas law and equation 5 that at the critical temperature,

$$[19] \quad \frac{\partial P}{\partial T} = \frac{7.654 P}{T}.$$

This equation can be obtained directly from equation 18 but the constant is then unknown.

SUMMARY.

1. It is shown that the $\frac{\partial P}{\partial T}$ for a liquid (vapor) at the critical temperature is exactly twice what it would be for the same substance as a gas occupying the critical volume.

2. It is shown that Biot's formula for vapor pressure cannot be made exactly to fit the true vapor pressure curve in the immediate neighborhood of the critical temperature. When

the pressure is considered the proportional error is very small. When the $\frac{\delta P}{\delta T}$ is considered the proportional error is large, and the values obtained from Biot's formula are too small.

3. The equation, $\frac{L - E_i}{\sqrt[3]{d} - \sqrt[3]{D}} = \mu'$, where μ' is the constant of molecular attraction, is shown to be applicable with exactness in the immediate neighborhood of and at the critical temperature for fifteen out of nineteen substances considered. The equation has already been proved accurate at lower temperatures.

It is shown that the constant of molecular attraction, μ' , can be calculated from the critical constants and the molecular weight.

5. The known fact that the ratio of the theoretical to the critical density is a constant for all substances is shown to follow necessarily from the fundamental ideas and equations upon which this series of papers is based.⁷

*University of North Carolina,
April 3rd, 1906.*

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NO. 3

PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY.

155TH MEETING, OCTOBER 11, 1904.

Professor William Cain, President, in the chair.

The following papers were presented:

The Construction of a Double Six—*A. Henderson.*

The Geological History of Currituck Banks—*Collier Cobb.*

A. S. WHEELER,
Recording Secretary.

156TH MEETING, NOVEMBER 8, 1904.

Professor William Cain, President, in the chair.

The following papers were presented:

Molecular Attraction—*J. E. Mills.*

Experiments on the Development of the Skeleton in Sponge Larvae—*H. V. Wilson.*

The Theories of Dyeing with Special Reference to the Constitution of Cellulose—*A. S. Wheeler.*

A. S. WHEELER,
Recording Secretary.

157TH MEETING, JANUARY 10, 1905.

Professor William Cain, President, in the chair.

The following papers were presented:

The Theory of Metal or Re-enforced Concrete Domes—*William Cain.*

Steel Hardening Metals—*J. H. Pratt.*

A. S. WHEELER,
Recording Secretary.

158TH MEETING, FEBRUARY 14, 1905.

Professor William Cain, President, in the chair.

The following papers were presented:

Mode of Inspection of the Hookworm Disease—*R. H. Whitehead.*

The Mystic Hexagram—*Archibald Henderson.*

Statistics of Cotton Manufacturing in the South—*C. L. Raper.*

A. S. WHEELER,
Recording Secretary.

159TH MEETING, MARCH 14, 1905.

Professor William Cain, president, in the chair.

The following papers were presented:

Normal Paper—*A. S. Wheeler.*

The Mutation Theory—*W. C. Coker.*

Chemical Affinity: A Method for Distinguishing Chemical Energy from Simultaneous Physical Energy Changes—*J. E. Mills.*

A. S. WHEELER,
Recording Secretary.

160TH MEETING, APRIL 11, 1905.

Professor William Cain, president, in the chair.

A motion was made and carried that the old arrangement

with the North Carolina Academy of Science be changed to read as follows: The Mitchell Journal to publish minutes and abstracts of papers for the annual meeting of the North Carolina Academy of Science for the sum of fifty dollars a year and that The Journal be sent to all members of the Academy, but not to the associate members.

The following papers were presented:

The Edison Storage Cell—*J. E. Latta.*

The Organization of the Ovum—*H. V. Wilson.*

Autophytographs—*Collier Cobb.*

A. S. WHEELER,
Recording Secretary.

BUSINESS MEETING, SEPTEMBER 27, 1905.

Professor William Cain, president, in the chair.

Officers for the ensuing year were elected as follows:

President, H. V. Wilson.

Vice-President, Archibald Henderson.

Corresponding Secretary, F. P. Venable.

Recording Secretary, A. S. Wheeler.

Editorial Committee on The Journal: W. C. Coker, Chairman; Archibald Henderson, J. E. Latta.

A. S. WHEELER,
Recording Secretary.

SOME PROBLEMS IN THE CELLULOSE FIELD.*

BY ALVIN S. WHEELER.

Professor of Chemistry, University of North Carolina.

The vegetable cell is a laboratory in which are carried out a most remarkable series of chemical reactions. As we contemplate the immense number of organic compounds of all degrees of compounds which are formed within the walls of the plant cell we are convinced that this is the chemical laboratory par excellence. Two features impress us particularly: first, the silence in which the operations are carried on; second, the narrow range of medium temperatures required. Notwithstanding this apparent simplicity of conditions the products are of the most various kind. Some of these man is able to synthesize in his own crude way; others are still the secrets of nature. It is utterly impossible for man to prepare certain naturally occurring compounds except at a temperature which would burn the plant tissue. We are led to wonder whether forces exist of which we are unacquainted or whether we are merely unable to control the forces already familiar to us. It would be difficult to say which supposition is the more probable. It will be granted that investigation into the activities of the cell is of profound importance. In fact it has been said that "it is in the plant cell where synthetical operations are predominant that we have to look for the foundations of the 'new chemistry' which may be expressed broadly as the relation of matter to life."

Among the products which result from the activities of the cell is cellulose, an essential constituent of all plant tissue. Plant physiologists have been accustomed to identify cellulose

*Reprinted from *The Chemical Engineer*, Vol. II., No. 8, July, 1905.

with the cell wall, but modern investigation has demonstrated the error of this belief by showing that the ultimate products of hydrolysis of different cell walls are not the same. Cotton, for instance, yields dextrose; the cell walls of the seeds of *Lupinus luteus*, and many other plants give galactose, while the seeds of the cereals and leguminous plants yield arabinose and xylose. It is clear that cell walls are not of uniform composition. How they actually differ has not yet been determined, their differentiation being an extremely difficult problem. The name cellulose does not apply to a single individual, existing in only one form, like ethyl alcohol. Analyses of various bodies regarded as cellulose give figures leading to the empirical formula $(C_6H_{10}O_5)_n$ in which the carbon percentage is 44.2 and the hydrogen is 6.3. The highest percentage of cellulose is obtained from cotton, the yield being approximately ninety per cent. Most of the remainder is water, and there are very small amounts of ash and complex organic compounds. Flax, hemp and ramie also give large yields of cellulose. Again, cellulose is used to designate combinations of the body already mentioned with highly complex radicals of unknown constitution. These are compound celluloses and are more specifically termed lignocelluloses, muco-celluloses, pectocelluloses, adipocelluloses and cutocelluloses. Some progress has been made in the constitutional study of these compounds, more especially the lignocelluloses. Cross and Bevan have studied the lignocellulose of jute, selecting this form because it seemed likely to be the simplest representative since jute matures in one season. They recognize the following general constituents: (a) α -cellulose, an oxidized cellulose; (b) β -cellulose, a less resistant form and yielding a large amount of furfural on hydrolysis; (c) lignone, a radical containing the carbonyl group and about one-third of which is of the benzeneoid type.

The difficulties surrounding the experimental study of the celluloses are very great. Their insolubility in the ordinary solvents precludes purification in the usual way and renders

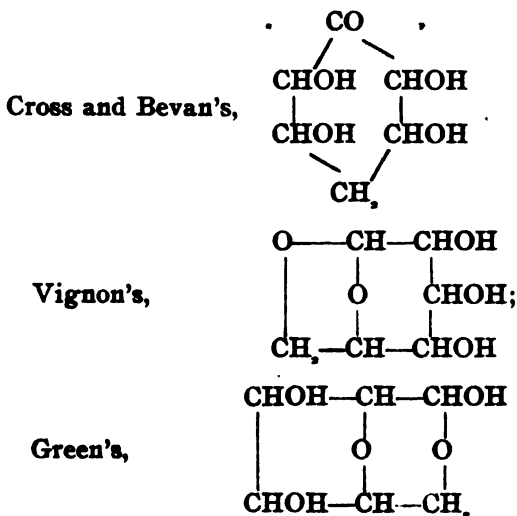
impossible any molecular weight determinations by the freezing or boiling point methods. They dissolve in a concentrated aqueous solution of zinc chloride and in cuprammonium, forming colloidal solutions from which they may be precipitated as gelatinous hydrates. The fact that they are colloids presents one reason why chemists have not been more attracted to their study. Colloids have been very unmanageable, but it is very noticeable that an increased amount of work is being done upon them. In the year 1890 only three communications upon colloids appeared, while in 1900 there were twenty-three. A brief statement of their properties is sufficient to show their unattractiveness. They possess little affinity, do not crystallize, dissolve to an indefinite degree in a very limited number of solvents, are filtered by animal membranes and form gelatinous precipitates. According to one view which is held by many we have in the colloidal solution not a solution at all, but a suspension of very finely divided particles which are much larger than simple molecules. In view of their precipitation by electrolytes their study is being prosecuted by electro-chemists and, although more attention is being paid to the inorganic colloids, the whole subject is undergoing development. As new light is obtained, a deeper insight into the character of the celluloses will necessarily follow. It will help to make possible a scientific classification, something which is lacking at present.

The formation of the celluloses is one of the most interesting problems connected with them and a very fundamental, one, too. What is the antecedent of cellulose? Durin has observed the formation in beet juice of a white insoluble substance, possessing the characteristic of cellulose. If this substance is transferred to a pure cane sugar solution, more of it is formed. These observations point to cane sugar as the predecessor of cellulose. The more elaborate investigations of Brown and Morris point more clearly to the same conclusion. Their study of foliage leaves persuaded them that starch is not the raw material out of which cellulose is built

up, but that is rather a reserve material to be drawn upon in case of cell starvation, that is, when all the cane sugar has been translocated as dextrose and levulose. The problem can not be regarded as settled and further work in this direction is highly desirable.

As already stated, the simple celluloses are represented by the empirical formula $(C_6H_{10}O_5)_n$, the letter n standing for a number which is wholly problematical, although Bumcke and Wolfenstein have suggested 12. As for a constitutional formula this has yet to be worked out. How much progress has been made and what remains to be done? The great stability of cellulose, made familiar by its almost universal use as a filtering medium, has precluded in the minds of many of us a realization of the chemical activity which it really possesses. Its attraction for water is very strong, cotton cellulose retaining from six to twelve per cent. in the air-dried condition, and if this water is driven off, it will be reabsorbed on exposure to the atmosphere. This hygroscopic property bears an undetermined relation to the presence of hydroxyl groups because it decreases as the number of hydroxyl groups is diminished by substitution of acid radicals. Since the tetracetate seems to be the highest normal acetate, it is probable that there are four hydroxyl groups. The other oxygen atom is combined with carbon to form a carbonyl group, although this is not in the usual reactive condition. In the easily derived hydro- and oxy-celluloses it appears at once in natural character of a reducing agent. The large proportion of acetic acid obtained when cellulose is fused with alkaline hydroxides indicates the presence of $CO-CH_3$ groups. Its resistance to the action of halogens and alkalis shows it to be a saturated compound. Owing to the similarity of the empirical formula of cellulose and starch and to their association in the processes of nature, it has been customary to regard them as very closely related in constitution. However, there is undoubtedly a fundamental difference between them. Vignon has subjected purified cotton and starch to hydrolysis with

dilute hydrochloric acid at 100°. The percentage yields of reducing products equal to dextrose were as follows: cotton, 3.29; starch, 98.6. Fenton and Gostling have brought out another striking behavior. Cotton cellulose is acted upon by dry hydrobromic acid in ethereal solution producing w-Brom-methylfurfural, a 33 per cent. yield being obtained. Under the same treatment potato starch yielded only 3.7 per cent. The belief is growing that cellulose does not belong to the straight chain compounds with the sugar and starches, but is instead a ring compound. Three formulae have been proposed for the unit group, $C_6H_{10}O_5$, as follows:

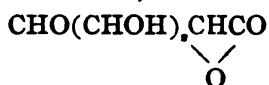


Any general theory of dyeing must take into account the constitution of cellulose. The three theories which have been held are (a) the mechanical, (b) the solid solution, and (c) the chemical. In view of the diverse chemical character of the three most important textile materials, silk, wool and cotton, it seems improbable that one theory will ever occupy the field to the exclusion of the other two. There are no reasons a priori for not combining the three by select-

ing what truth there may be in each one. The attempts to hold to one theory have been attended with serious difficulties. As for cellulose (cotton and linen fabrics) its nature as a chemical compound comes into play in certain dyeing processes. It behaves as a weak acid and if this acid character is increased by conversion into oxycellulose, it exhibits an increased affinity for basic dyes. On the other hand, Vignon has caused cotton by treatment with ammonia under various conditions to take up as much as 2.86 per cent. N which is not extracted by dilute hydrochloric acid and now, possessing basic properties, it will take an acid dye from an acid bath. These reactions seem to be cases of simple salt formation. As for the solid solution theory Witt regards substantive dyeing as a case of one solid dissolving another. The dye, being more soluble in the fibre than in the water, is extracted therefrom by the fibre and in the fibre the dye exhibits the same characteristics which it shows in aqueous solution. According to this view the chemical nature of the textile is of no consequence except as it affects its solvent capacity. The behavior of cellulose with certain dyes does not seem to militate against this view. The general question is constantly under investigation.

Although cellulose is distinguished by its permanence, it is attacked by a great variety of oxidizing agents. The product, called oxycellulose, is not uniform in character and experimenters seldom agree in their analytical data. Bumcke and Wolffenstein recently discarded the term oxycellulose and re-opened the whole question. The action of hydrogen peroxide upon filter paper was studied. They came to the conclusion that cellulose can not undergo simple oxidation without hydrolysis. They substitute the name hydracellulose for oxycellulose, this name indicating the hydrolytic production and aldehydic properties of the product. It bears the same relation to cellulose as glucose to cane sugar. Tollens has also recently investigated the oxycellulose and proposes the

name celloxin for a body with the formula $C_6H_8O_6$, or $C_6H_{10}O_6$, believing that the oxycelluloses are varying mixtures of cellulose with celloxin. Attempts to isolate celloxin have been unsuccessful. Vignon suggests that oxycellulose consists of three molecules of cellulose associated with the group



which is at once an aldehyde, an alcohol and a lactone. The unsettled state of this part of the field is apparent.

The fermentation of cellulose, although an important question, has been studied by a few investigators only, notably Hoppe-Seyler, Tappeiner, Omelianski and Van Senus. Insufficient work has been done upon pure cellulose and I have undertaken this phase of the investigation. Van Tieghen states that the cellulose ferment corresponds in properties with "amylobacter," a bacterium described by him, and it has been commonly asserted since that this was the cellulose ferment. Van Senus regards this as extremely doubtful, since these bacteria do not attack cellulose suspended in a meat extract solution. The fermentation is anaerobic and the products of decomposition are hydrogen, carbon dioxide, methane, acetic and butyric acids, the proportions varying with the conditions. If the fermentation can be carried out so that an intermediate product like alcohol is obtained, a discovery of tremendous importance will have been made. The subject of fermentation is also important in its relation to digestion not only in the human species but more especially in herbivorous animals.

Through the decomposition of cellulose by chemical reagents there are obtained oxalic acid, alcohol and sugar, according to the conditions employed. Classen has gotten out a number of patents for the production of sugar (dextrose) from wood and he makes the startling claim that sulphuric acid converts all of the cellulose in wood into sugar. When

we consider the vast waste of cellulose in the form of sawdust (acres of it about a single saw mill) the possibilities of a new source of sugar (and from that, alcohol) are extremely interesting.

Cellulose is acquiring a greater and greater importance in the arts and manufactures. Its use as a paper stock and as a raw material for clothing place it in the front rank of industrial products. Some of its derivatives also find extensive application, the nitro-celluloses for explosives, artificial silk and celluloid, and the thiocarbonate for artificial silk. The tetracetate has been found to possess insulating powers superior to gutta-percha and it is now a commercial product. If a solution of the acetate is allowed to evaporate a film of great tenacity is obtained which may be used in photography and for laquering metals. An acetate may also be obtained in the form of a powder, soluble in chloroform and nitrobenzol. This is used for preparing substances resembling celluloid and as a substitute for collodion. Its advantages lie in the fact that it is odorless and is not inflammable. Two problems which have not been seriously attacked are the conductivity of pure cellulose and the use of cellulose as a membrane in osmotic work. Many other questions of varying degrees of importance might be mentioned.

In concluding this brief survey I wish to express my agreement with the idea now often expressed that the demarcation line between the scientific and the practical has hitherto been too sharply drawn. Professor Jordan recently said: "It is often a temptation to distinguish radically between pure science and applied science and to look upon the latter as unworthy the attention of the philosophically minded. True science can admit of no such distinction," and President Jordan says, "Applied science can not be separated from pure science, for pure science may develop at any quarter the greatest and most unexpected economic values, while, on the other hand, the applications of knowledge must await the

acquisition of knowledge before any high achievement in any quarter can be reached. * * * Whatever is true is likely sometime to prove useful and all error is likely sometimes to prove disastrous."

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EXPERIMENTS ON THE PRODUCTION OF CRUDE TURPENTINE BY THE LONGLEAF PINE.

BY CHAS. H. HERTY, PH.D.

With the hope of improving the method of distillation commonly practiced in the production of spirits of turpentine from the crude resin of the Longleaf Pine, the writer, at that time connected with the University of Georgia, began a systematic study of conditions throughout the turpentine belt. Information was gathered from publications of the U. S. Department of Agriculture and from correspondence with leading men in the naval stores industry, railroad officials and others.

It soon became apparent that the industry, which had started on a rather small scale in eastern North Carolina, had grown to large proportions, affording employment to thousands of laborers and furnishing the world with at least nine-tenths of the spirits of turpentine and rosin used in manufactures. It also became evident that during this period of growth the forests of North Carolina and South Carolina had been almost completely exhausted, while those of Georgia were being rapidly destroyed. Throughout the territory methods of operation were absolutely uniform. A visit to different sections showed at once the explanation of the complete destruction of the forests in the Carolinas, for in addition to the removal of timber by the lumbermen, fires and storms following in the wake of the turpentine operator had completed the destruction. It needed no close observation to determine at once that the chief cause of this destructive action by fires and storms was the "box", a large and deep hole cut into the trunk of the tree at its base to receive the

resin which exudes during the spring and summer months from the freshly scarified trunk above.

In the cutting of the "box" or "boxes" in the base of the tree its trunk is partly severed and in storms splits off at the top of the box, breaking usually three or four feet higher.

Again, the turpentine belt is characterized by a complete ground covering of "wire grass" whose exposed blades die during winter and are annually burned off in the early spring months to furnish better grazing for cattle. So long as turpentine operations are active, these ground fires do not damage the trees, for during the winter the laborers remove with hoes all wire grass and fallen straw a safe distance from each tree; but when the forest is abandoned, this precaution is no longer taken and with the next fire the resin which has gradually accumulated in the old "box" takes fire, the heat melts the resin on the scarified surface above which, flowing into the box, adds fuel to the flames until the tree falls; or if the case is not so extreme, until the tree is weakened to such an extent that it can no longer resist the attacks of injurious insects which soon kill it.

The evident loss from this factor was so much greater than from imperfections in the method of distillation that common sense prompted that immediate efforts be diverted from the matter of distillation to that of a practical device for collecting the resin which would render unnecessary the cutting of the "box". Many evidences were found of unsuccessful efforts to introduce a form of a cup system, some of these being identical with the cup system used in the turpentine forests of France since 1860. But none had found any permanent place in the industry.

With a simple apparatus somewhat like the French, consisting of a cup and two metallic troughs, preliminary experiments were begun during the summer vacation of 1901 at Statesboro, Ga. The metallic troughs or gutters, consisting of two inch strips of sheet galvanized iron, bent along the middle to form a trough, are inserted in inclined shallow cuts

across flattened surfaces of the tree and serve to lead the resin to a central point. One of the gutters is slightly higher than the other, delivering its resin into the lower gutter, from the end of which all the resin drips into the cup suspended on a nail just below. Such an apparatus can at the end of each season be easily raised to a point near the scarification surface. With this apparatus tests were made primarily of its practicability and effectiveness. Further, the quality of the resin exuding from the trees in successive years of operation was determined. Under the "box" system the resin of the second, third and fourth years of operation shows gradually increasing coloration and the rosin left after distillation of the volatile spirits of turpentine is a deeper red and less valuable. With the cup and gutters placed near the freshly scarified surface, it was proved that the quality of the resin so far as concerns color is as good in the fourth as in the first year, the color of the resin from the old "boxes" being due to absorption of the highly colored oxidized resin on the long surface above the "box". Quantitative experiments were made upon the loss of resin which falls outside of the "box", due to trunks not perpendicular, and of the loss of volatile spirits of turpentine during the long flow to the "box". It was also shown that different portions of the circumference of a tree, in many cases, vary greatly in ability to produce resin, and that the underside of a leaning tree is much more productive than the upper side. The daily rate of flow after scarification was studied and it was found that in general, sixty per cent. of the flow takes place during the first period of twenty-four hours, twenty-five during the second and after seven days, the flow practically ceases. Numerous other studies were projected and some were partly carried out, but the summer vacation being ended, it was necessary to discontinue the work in the field.

The interest of the U. S. Bureau of Forestry was aroused by these preliminary experiments and by the promise of prac-

tibility in the simple apparatus used. This led the writer during the following winter to accept a commission from the Bureau to undertake field experiments on a commercial scale to test further the usefulness of the apparatus in the hands of the average turpentine laborer, and to determine the important question of whether or not the cutting of the box decreases the productive power of the tree.

Crude turpentine (resin) is a pathological product, resulting from the wound given the tree in scarification. It is necessary to wound the tree to get the flow of resin, but the cutting of the "box" is an unnecessary and intense wound and it seemed reasonable to expect that in comparative experiments trees which are not "boxed" would, with all other conditions equal, show an increased yield.

These field tests were carried out at Ocilla, Ga., on the place of Messrs. Powell, Bullard & Co. About twenty-five thousand trees were used during the first year. From one-half of these the resin was collected in the usual "box"; on the other half cups and gutters were placed. Four distinct sets of experiments were made corresponding to first, second third and fourth years of operation, five thousand cups and five thousand boxes in each set. Every precaution was taken to insure uniformity of conditions between the two halves of each set, or "crop" as designated in turpentine operating. Careful record was kept of the yield from all of the eight half "crops", each being separately distilled and the products sold separately. The results of the year's tests were published by the Bureau of Forestry as Bulletin No. 40, entitled "A New System of Turpentine Orchardng".

After the first year, the experiments were continued only on one of the four sets, that designated "first" above, for only in this set did full conditions for comparative results obtain, one-half of the trees in this set never having been "boxed", while in the other three sets, all of the trees had been boxed in previous years of operation.

After conducting the tests three years, the experiments

were discontinued and the results published by the Bureau of Forestry as Circular No. 34 entitled "Practical Results of the Cup and Gutter System of Turpentinizing". The summary of these results shows the total value of the products (spirits of turpentine and rosin) from three years of operation to have been from

the cupped half-crop.....	\$2,688.55
the boxed half-crop.....	2,046.53

Gain from cupped half-crop.....\$ 642.02

an increase of about 32 per cent over the "box" system.

The results of the first year of operation of these two half-crops, during which time conditions were identical in each except that in one half crop "boxes" had been cut in the trees, showed an increased yield from the unboxed trees of 23.5 per cent., thus confirming the hypothesis that the cutting of the box decreased the productive power of the tree.

The publication of these results has resulted in the commercial introduction of the system on a large scale, and in many cases the results obtained with the apparatus have exceeded those obtained in the experimental tests.

But the introduction of the cup system cannot of itself save the forests of Longleaf Pine from destruction. If too great a proportion of the circumference of the tree be removed in scarification, or "chipping" as it is termed, the tree will die whether a "box" has been cut or a cup hung. Further experiments have, therefore, been begun by the Bureau of Forestry to determine to what extent the wound given in "chipping" can be decreased in width, height and depth without decreasing the production. It is possible that by moderate reduction the production may even be increased. These experiments are now in progress.

A MEMOIR ON THE TWENTY-SEVEN LINES UPON A CUBIC SURFACE.

PART II.

ARCHIBALD HENDERSON, PH.D.

CHAPTER II.

THE CONFIGURATION OF THE DOUBLE-SIX. AUXILIARY THEOREMS.

§5. *The Double-Six Notation.*

Let us write down, in Salmon's notation, two systems of non-intersecting lines

$$\begin{array}{l} ab, cd, ef, (ad \cdot cf \cdot eb), (ad \cdot cf \cdot eb), (ad \cdot cf \cdot eb), \\ cf, eb, ad, (ab \cdot cd \cdot ef), (ab \cdot cd \cdot ef), (ab \cdot cd \cdot ef). \end{array}$$

In this scheme, according to former postulation (§4), each line of one system does not intersect the line of the other system, which is written in the same vertical line, but does intersect the five other lines of the second system.

The configuration was first observed by Schläfli* and was given by him the name it has since borne—a “double-six”. The concept of the double-six lies at the very basis of the study of the lines upon a cubic surface and the notation

*“An attempt to determine the twenty-seven lines upon a surface of the third order, and to divide such surfaces into species in reference to the reality of the lines upon the surface”, *Quarterly Journal of Math* (1858), vol. II, pp. 55-65, 110-120.

derived therefrom is the most simple and convenient that has yet been discovered for the 27 lines and 45 triple tangent planes.

NOTATION. Starting with the double-six, written

$$\begin{array}{c} a_1, a_2, a_3, a_4, a_5, a_6 \\ b_1, b_2, b_3, b_4, b_5, b_6 \end{array}$$

we are enabled to express the complex and diversified symmetry of the 27 lines and 45 triple tangent planes in unique and simple form.

Returning to the double-six, written in Salmon's notation, it appears that the lines ab , cb , and eb lie in the same plane and are the only three of the 27 lines that lie in the plane b . In like manner cb , cd , and cf all lie in the plane c and hence the line that lies in the plane of ab and eb is identical with the line that lies in the plane of cd and cf , viz., the line cb .

In the new notation, we shall call the third line in the plane of a_1 and b_2 which intersect, the line c_{12} , and the triangle so formed shall be designated by 12. As has been shown above, the side c_{12} forms with a_1 and b_2 a triangle, designated 21. Hence we have 15 ($\equiv c_2$) lines c , each of which intersects only those four lines a, b the suffixes of which belong to the pair of numbers forming the suffix of c . For suppose c_{12} should intersect any other line, say a_3 , of the eight lines $a_1, a_2, a_3, a_4, a_5, a_6; b_1, b_2, b_3, b_4, b_5, b_6$. Then c_{12} intersecting a_1, b_1, a_2 and b_2 , already, c_{12}, a_1, b_1 and c_{12}, a_2, b_2 form two triangles, and since they have two lines in common, their planes are identical and consequently b_1 intersects b_2 , contrary to hypothesis.

Any two c 's, the suffixes of which have a number in common, do not intersect. For suppose c_{12}, c_{13} intersect; they form a plane in which a_1 and b_1 lie and therefore a_1 meets b_1 , contrary to hypothesis. It may also be shown that any two c 's, the suffixes of which have no number in common, do intersect.

These facts may be briefly put as follows:

$$\left. \begin{array}{l} c_{ij} \text{ intersects } a_i, b_j; a_j, b_i \\ c_{ij} \text{ intersects } c_{kl} \\ c_{ij} \text{ does not intersect } c_{ik} \\ c_{ij} \equiv c_{ji} \\ \Delta_{ij} \text{ is not equal to } \Delta_{ji} \end{array} \right\} \begin{array}{l} (i, j, k, l = 1, 2, \dots, 6) \\ i, j, k, l, \text{ all distinct} \end{array}$$

We see then that there are triangles of the form c_{12}, c_{34}, c_{56} , which may be briefly represented by $12 \cdot 34 \cdot 56$. Hence there are thirty (${}_6P_3$) triangles of the type 12 and fifteen of the type $12 \cdot 34 \cdot 56$. The latter arises from the fact that, if we fix our attention upon 12 , the other two sets may be written in only three ways.

§6. History of the Theorem.

In 1858 Schläfli (*l. c.*) proved the double-six theorem incidentally in connection with his investigations on the 27 lines on the cubic surface. He enunciated the theorem in the following form:—

Given five lines a, b, c, d, e , which meet the same straight line X ; then may any four of the five lines be intersected by another line. Suppose that A, B, C, D, E are the other lines intersecting (b, c, d, e) , (c, d, e, a) , (d, e, a, b) , (e, a, b, c) and (a, b, c, d) respectively. Then A, B, C, D, E will all be met by one other straight line x .

The double-six in this case is written

$$\left(\begin{array}{c} a, b, c, d, e, x \\ A, B, C, D, E, X \end{array} \right)$$

Schläfli then proposes the question—"Is there, for this elementary theorem, a demonstration more simple than the one derived from the theory of cubic forms?"

Sylvester* states that the theorem admits of very simple

*Note sur les 27 droites d'une surface du 3^e degré," *Comptes Rendus*, vol. LII (1861) pp. 977-980.

geometrical proof but he did not give the proof. Salmon* has given a method for geometrically constructing a double-six but I do not understand it to be a PROOF of the theorem, independent of the cubic surface.

In 1868 Cayley† gave a proof of the theorem from purely static considerations, making use of theorems on six lines in involution. Again in 1870 Cayley‡ verified the theorem, using this time his method of the six co-ordinates of a line. Kasner|| has recently given a proof by using the six co-ordinates of a line.

The method I have adopted in the following is independent of the theory of cubic surfaces.

[NOTE. This proof and a model of the configuration constructed in Nov. 1903, were presented by me before the Chicago Section of the Am. Math. Society on April 11th, 1903. I had not at that time seen Kasner's article in the April, 1903, number of the American Journal, an article having points of contact with mine.]

§7. *Proof of the Double-Six Theorem.*

Representing the double-six in the Schläfli-Cayley notation

$$\begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 1' & 2' & 3' & 4' & 5' & 6' \end{pmatrix}$$

it is seen that these 12 lines have the thirty intersections P_{ij} ,

*Geometry of 3 Divisions, 4th edition, p. 500.

†"A 'Smith's Prize' Paper; Solutions", Coll. Math. Papers, vol. VIII (1868) pp. 480-481.

‡"On the Double-Sixers of a Cubic Surface", Coll. Math. Papers, vol. VII., pp. 316-380; Quarterly Journal of Mathematics, vol. X, (1870) 58-71.

||"The Double-Six Configuration Connected with the Cubic Surface, and a Related Group of Cremona Transformations", American Journal of Mathematics vol. XXV, No. 2 (1903), pp. 107-122.

	1	2	3	4	5	6
1'		.	.	.	.	.
2'	.		.	.	.	.
3'	.	.		.	.	.
4'	.	.	.		.	.
5'	.	.	.	.		.
6'	.	.	.	.	.	

and determine thirty planes Π_{ij}' , (formed by the lines i and j').

Using quadriplanar co-ordinates, I choose for the lines 1', 3', 4', 5', 6' the following equations:

$$1' : \delta\delta Cx + \delta\delta Az - (a'\gamma\delta - a\gamma\delta)w = 0, \quad y = 0$$

$$3' : \gamma\gamma Dy - (\beta'\gamma\delta - K\beta\gamma'\delta)z + \gamma\gamma Bw = 0, \quad x = 0$$

$$4' : \quad \quad \quad z = 0, \quad w = 0$$

$$5' : \delta x - a'w = 0, \quad \gamma'y - \beta'z = 0$$

$$6' : \delta x - aw = 0. \quad \gamma\gamma - \beta z = 0$$

where we set

$A, B, C, D \equiv (a' - Ka), (\beta' - K\beta), (\gamma' - K\gamma), (\delta' - K\delta)$ respectively.

These five lines have a common tractor* since the determinant

*Cayley uses the word 'tractor' to denote a line which meets any given lines.

$$\Delta_5 = \begin{vmatrix} 0, (12), (13), (14), (15) \\ (21), 0, (23), (24), (25) \\ (31), (32), 0, (34), (35) \\ (41), (42), (43), 0, (45) \\ (51), (52), (53), (54), 0 \end{vmatrix} \equiv 0$$

this being the condition* that any five lines 1, 2, 3, 4, 5 say, have a common tractor, where the equations of lines i and j are

$$\left. \begin{aligned} a_i x + b_i y + c_i z + d_i w &= 0 \\ a_j x + \beta_j y + \gamma_j z + \delta_j w &= 0 \end{aligned} \right\} \dots\dots\dots (i)$$

and

$$\left. \begin{aligned} a_j x + b_j y + c_j z + d_j w &= 0 \\ a_j x + \beta_j y + \gamma_j z + \delta_j w &= 0 \end{aligned} \right\} \dots\dots\dots (j)$$

respectively, and we understand by (ij) the determinant

$$\begin{vmatrix} a_i, & b_i, & c_i, & d_i \\ a_j, & \beta_j, & \gamma_j, & \delta_j \\ a_j, & b_j, & c_j, & d_j \\ a_j, & \beta_j, & \gamma_j, & \delta_j \end{vmatrix}$$

The five lines 1', 3', 4', 5', 6' constituting the co-tractorial quintuple do not mutually intersect, since in forming the determinants (ij) , none of them are found to vanish. A possible difficulty arises from the fact that the hyperboloid through any three of these five collinear lines might touch a fourth, that is to say that certain four of the lines might have a double tractor.† That such is not the case appears in the sequel.

Determining now the common tractor, 2, of these five lines, we find it to have the equations

*Sylvester, "Note sur l'involution de six lignes dans l'espace", *Comptes Rendus*, vol. LII (1861), pp. 815-817.

†Cayley, "On the Six Co-ordinates of a Line". *Trans. Camb. Phil. Soc.*, vol. XI, part II (1869) pp. 290-323.

$$2 : \quad \begin{cases} \gamma' B (\delta' x - a' w) - \delta' A (\gamma' y - \beta' z) = 0 \\ \gamma B (\delta x - a w) - \delta A (\gamma y - \beta z) = 0 \end{cases}$$

Now, in general, four given lines have a pair of tractors. Since the five lines 1, 3', 4', 5', 6 already have a single tractor 2, they have, in sets of four, five more tractors, thus:—the lines 1, 3, 4, 5, 6 are tractors of the sets (3', 4', 5', 6'), (1', 4', 5', 6'), (1', 3', 5', 6'), (1', 3', 4', 6'), (1', 3', 4', 5') respectively.

Let us proceed to determine the equations of the five lines 1, 3, 4, 5, 6. Recalling the values of A, B, C and D above, it is obvious by inspection that the equations of lines 1 and 3, meeting the quadruples (3', 4', 5', 6') and (1', 4', 5', 6') respectively, are

$$1 : \quad x = 0, w = 0$$

$$3 : \quad y = 0, z = 0.$$

The equations of line 4, since it meets the lines 5' and 6', are of the form

$$\left. \begin{aligned} \frac{x}{a'} - \lambda \frac{y}{\beta'} + \lambda \frac{z}{\gamma'} - \frac{w}{\delta'} &= 0 \\ \frac{x}{a} - \lambda \frac{y}{\beta} + \mu \frac{z}{\lambda} - \frac{w}{\delta} &= 0 \end{aligned} \right\}$$

The conditions that this line meet the line 1', written in the form

$$\left(\frac{x}{a'} + \frac{z}{\gamma'} - \frac{w}{\delta'} \right) \frac{1}{a\gamma} - k \left(\frac{x}{a} + \frac{z}{\gamma} - \frac{w}{\delta} \right) \frac{1}{a'\gamma'} = 0, y = 0$$

are given by

$$\lambda = 1, \mu = 1.$$

Then the line 4 has the equations

$$4 : \left\{ \begin{array}{l} \frac{x}{a} - \frac{y}{\beta} + \frac{z}{\gamma} - \frac{w}{\delta} = 0, \\ \frac{x}{a'} - \frac{y}{\beta'} + \frac{z}{\gamma'} - \frac{w}{\delta'} = 0 \end{array} \right\}$$

and we see by inspection that this line meets the line 3' when we write its equations in the form

$$3' : \left(-\frac{y}{\beta'} + \frac{z}{\gamma'} - \frac{w}{\delta'} \right) \frac{1}{\beta\delta} - k \left(-\frac{y}{\beta} + \frac{z}{\gamma} - \frac{w}{\delta} \right) \frac{1}{\beta'\delta'} = 0,$$

$$x = 0.$$

Line 5, since it meets the lines 4' and 6', has equations of the form

$$\left. \begin{array}{l} z - \lambda w = 0 \\ \left(\frac{x}{a} - \frac{w}{\delta} \right) - \mu \left(\frac{y}{\beta} - \frac{z}{\gamma} \right) = 0 \end{array} \right\}$$

Meeting line 3' (see form last written), it is necessary to identify the equations

$$-\frac{\mu}{\beta} y + \frac{\mu}{\gamma} z - \frac{w}{\delta} = 0$$

$$-\frac{1}{\delta} \left(\frac{\delta' - k\delta}{\beta' - k\beta} \right) y + \frac{(\gamma\beta'\delta' - k\gamma'\beta\delta)}{\gamma'\delta(\beta' - k\beta)} z - \frac{w}{\delta} = 0$$

wherefore

$$\mu = \frac{\beta}{\delta} \left(\frac{\delta' - k\delta}{\beta' - k\beta} \right) = \frac{1}{\gamma'\delta} \frac{(\gamma\beta'\delta' - k\gamma'\beta\delta)}{\beta' - k\beta},$$

giving

$$\gamma' : \gamma = \beta' : \beta$$

for which
$$\mu = \frac{\gamma}{\delta} \left(\frac{\delta' - k\delta}{\gamma' - k\gamma} \right)$$

and accordingly

$$\frac{\delta}{\gamma} \left(\frac{\gamma' - k\gamma}{\delta' - k\delta} \right) \left(\frac{x}{a} - \frac{w}{\delta} \right) - \left(\frac{y}{\beta} - \frac{z}{\gamma} \right) = 0$$

Applying similar reasoning to the equation

$$z - \lambda w = 0$$

with respect to the lines 1' and 3', we finally obtain

$$\lambda = \frac{\gamma'}{\delta'}$$

Then the equations of line 5 are

$$5: \quad \begin{cases} \delta'z - \gamma'w = 0 \\ \beta C(\delta x - a'w) - aD(\gamma y - \beta z) = 0. \end{cases}$$

Determining in a precisely similar fashion the equations of line 6, we find

$$6: \quad \begin{cases} \delta z - \gamma w = 0 \\ \beta' C(\delta' x - a'w) - a'D(\gamma' y - \beta' z) = 0 \end{cases}$$

It remains to show that the five lines 1, 3, 4, 5, 6 have a common tractor (in other words are collinear).

Writing out the various determinants (ij) and substituting in the formula for Δ_5 , we obtain (after reduction)

$$\Delta_5 \equiv 0$$

and hence these five lines have a common tractor (but are *not* mutually intersecting, since no (ij) = 0).

Determining now the equations of the line, called 2', which meets these five lines, we find

$$2' : \begin{cases} (\alpha\beta' - \alpha'\beta)\delta\delta' Cx + (\gamma\delta' - \gamma'\delta)\alpha\alpha' Bw = 0 \\ (\alpha\beta' - \alpha'\beta)\gamma\gamma' Dy + (\gamma\delta' - \gamma'\delta)\beta\beta' Az = 0 \end{cases}$$

Hence we reach the following conclusion, which is Schläfli's theorem:—

The five lines determined from five co-tractorial lines by choosing the remaining tractor in each set of four of the latter lines, are themselves co-tractorial.

In the above proof, the complete set of lines was derived from the five co-tractorial lines 1', 3', 4', 5', 6', but it is immaterial from which five of the primed or unprimed lines we start. Moreover the relation between the sets 1', 3', 4', 5', 6' and 1, 3, 4, 5, 6 is a reversible one—the lines of one set are the tractors of the other set by fours and *vice versa*.

§8. Anharmonic Ratios.

Let us next find the co-ordinates of the points of intersection of the lines 2', 3', 4', 5', 6' with the line 1. Determining these in the usual way and writing down also the co-ordinates of the vertex *C* of the fundamental tetrahedron *ABCD*, we tabulate them as follows;—

$P_{w'}$	0	$\beta\beta'(\gamma\delta' - \gamma'\delta)A$	$\gamma\gamma'(\alpha\beta' - \alpha'\beta)D$	0
$P_{v'}$	0	$\beta'\delta'\gamma - K\beta\delta\gamma'$	$\gamma\gamma'D$	0
$P_{u'}$	0	1	0	0
$P_{1'}$	0	β'	γ'	0
$P_{1''}$	0	β	γ	0
C	0	0	1	0

The anharmonic ratio of the four collinear points $P_{w'}$, $P_{1'}$, $P_{1''}$, $P_{v'}$ is identical with the anharmonic ratio of the four parameters

$$\frac{\gamma'(\alpha\beta' - \alpha'\beta)D}{\beta\beta'(\gamma'\delta - \gamma\delta')A}, \quad \frac{\gamma'D}{\beta'\delta'\gamma - K\beta\delta\gamma'}, \quad \frac{\gamma'}{\beta'}, \quad \frac{\gamma}{\beta}.$$

Calculating the value $\frac{\lambda_3 - \lambda_1}{\lambda_3 - \lambda_2} + \frac{\lambda_4 - \lambda_1}{\lambda_4 - \gamma_2}$ of the anharmonic

ratio of these four parameters numbered in the order in which they are written, we find

$$(P_{11}, P_{12}, P_{13}, P_{14}) = \frac{\beta\delta'}{K\beta\delta} \left\{ \frac{\beta(\gamma'\delta - \gamma\delta')A - \gamma(\alpha\beta' - \alpha'\beta)D}{\beta'(\gamma'\delta - \gamma\delta')A - \gamma'(\alpha\beta' - \alpha'\beta)D} \right\}.$$

Let us now determine the co-ordinates of the points of intersection of the lines 1, 2, 3, 5, 6 with the line 4'. These follow in the table below:

F_{14}	0	1	0	0
P_{14}	A	B	0	0
P_{13}	1	0	0	0
P_{12}	$\alpha\gamma D$	$\beta\delta C$	0	0
F_{11}	$\alpha'\gamma' D$	$\beta'\delta' C$	0	0

The anharmonic ratio of the four collinear points $P_{11}, P_{12}, P_{13}, P_{14}$, is identical with the anharmonic ratio of the four parameters

$$\frac{B}{A}, \quad 0, \quad \frac{\beta\delta C}{\alpha\gamma D}, \quad \frac{\beta'\delta' C}{\alpha'\gamma' D}.$$

Calculating the value $\frac{\mu_3 - \mu_1}{\mu_3 - \mu_2} + \frac{\mu_4 - \mu_1}{\mu_4 - \mu_2}$ of the anharmonic

ratio of these four parameters numbered in the order in which they are written, we find

$$(P_{\alpha'}, P_{\beta'}, P_{\gamma'}, P_{\delta'}) = \frac{\beta'\delta'}{\beta\delta} \left\{ \frac{\beta\delta AC - \alpha\gamma BD}{\beta'\delta' AC - \alpha'\gamma' BD} \right\}$$

Recalling the fact that

$$A, B, C, D \equiv (\alpha' - K\alpha), (\beta' - K\beta), (\gamma' - K\gamma), (\delta' - K\delta)$$

respectively, it is easily verified that

$$\begin{aligned} \frac{\beta'\delta'}{K\beta\delta} \left\{ \frac{\beta(\gamma'\delta - \gamma\delta')A - \gamma(\alpha\beta' - \alpha'\beta)D}{\beta'(\gamma'\delta - \gamma\delta')A - \gamma'(\alpha\beta - \alpha'\beta)D} \right\} \\ \equiv \frac{\beta'\delta'}{\beta\delta} \left\{ \frac{\beta\delta AC - \alpha\gamma BD}{\beta'\delta' AC - \alpha'\gamma' BD} \right\} \end{aligned}$$

Accordingly

$$(P_{12'}, P_{13'}, P_{14'}, P_{15'}) = (P_{\alpha'}, P_{\beta'}, P_{\gamma'}, P_{\delta'}),$$

or expressing this in a briefer fashion

$$(2', 3', 5', 6')_1 = (2, 3, 5, 6)_4$$

Since the configuration is a symmetrical one, we have the general conclusion

$$(i'_3, i'_4, i'_5, i'_6)_{t_1} = (i_3, i_4, i_5, i_6)_{t_4},$$

and this theorem may be phrased as follows:—

The anharmonic ratio of the points in which any four out of five co-tractorial lines cut the common tractor of all five is equal to the anharmonic ratio of the points where the fifth line is intersected by the correspondents of the first four.

Let us designate the anharmonic ratio of the four planes formed by the plane i'_1 with the lines i_3, i_4, i_5, i_6 by the symbol $(i_3, i_4, i_5, i_6)_{t_1}$. Recalling next the known theorem concerning the two tractors of four lines, viz. that the four points of either tractor and the four planes of the other tractor have the same anharmonic ratio, we obtain

$$(i_3, i_4, i_5, i_6)_{t_0} = \overline{(i_3, i_4, i_5, i_6)}_{t_1},$$

and have by our last theorem

$$(i'_3, i'_4, i'_5, i'_6)_{t_1} = \overline{(i_3, i_4, i_5, i_6)}_{t_1},$$

which may be phrased as follows:—

*The anharmonic ratio of the four points, on one of five co-tractorial lines, which are collinear with three of the remaining lines is equal to the anharmonic ratio of the four planes determined by these remaining lines and their common tractor.**

For other interesting results on the anharmonic ratios connected with the double-six configuration consult the paper of Kasner just referred to.

§9. *Five Co-tractorial Lines as Primitive.*

Given any five co-tractorial lines, these determine uniquely, as was shown in § 7, the double-six configuration. Then if we consider the plane of ij' , it will be met by the lines i, j in points which lie on the line ij . Since $P_1 = 15$, the 12 lines of the double-six together with the 15 new lines make up 27 in all, the total number upon the cubic surface.† Then the condition $\Delta_5 = 0$ (§7.), which is the condition that five lines be co-tractorial, is likewise the condition that five given lines may lie in a cubic surface. The result of Sylvester, viz. that $\Delta_5 = 0$ is the condition that five given lines be co-tractorial, is found in a paper on the "Involution of Six Lines",‡ a subject first studied by him in connection with a theorem in the *Lehrbuch der Statik*, by Möbius (Leipzig).

If we are given five lines, defined by their six co-ordinates

*Kasner, *Am. Journal Math.* vol. XXV, No. 2 (1903), p. 114.

†Sylvester, *Comptes Rendus*, vol. LII (1861), pp. 977-980. Of. also Salmon, *Geom. of Three Dimensions*, 4th edition, pp. 500-501 and B. Sturm, *Flächen Dritter Ordnung*, pp. 57-59.

‡*Comptes Rendus*, vol. LII (1861), pp. 815-817.

$(a_1, b_1, c_1, f_1, g_1, h_1), \dots (a_5, b_5, c_5, f_5, g_5, h_5)$, then the condition that these five lines be co-tractorial is also

$$\begin{vmatrix} 0, & 12, & 13, & 14, & 15 \\ 21, & 0, & 23, & 24, & 25 \\ 31, & 32, & 0, & 34, & 35 \\ 41, & 42, & 43, & 0, & 45 \\ 51, & 52, & 53, & 54, & 0 \end{vmatrix} = 0,$$

where we set

$a_1 f_5 + a_2 f_1 + b_1 g_5 + b_2 g_1 + c_1 h_5 + c_2 h_1 = 12$, &c.,*
which is also the condition that these lines may be in a cubic surface.†

The virtual identity of this condition with that of Sylvester ($\Delta_5 = 0$ of §7) is on account of the fact that Cayley's determinant of the fifth order above written is the square root of Sylvester's Δ_5 .‡

*Cayley, Coll. Math. Papers, vol. VII (1867), pp. 66-98.

†Cayley, Coll. Math. Papers, vol. VII (1870), p. 178.

‡Sylvester, Comptes Rendus, vol. LII (1861), p. 816.

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FOOD ADULTERATION.

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The human body is a chemical laboratory in which fires are kept up at night as well as by day. In it the most complicated chemical reactions are carried out, many of which man can neither reproduce nor understand. Some of the complex substances can be made by man at very high temperatures, but the body needs only its own moderate temperature. Here we come face to face with one of the wonders of nature. The food which we eat constitutes the fuel which feeds the fires, and if this is not what it purports to be, then abnormal substances are produced, the machine is thrown out of gear—in short, we are sick. The question of pure food is a vital one. That we do not always get it is absolutely certain. To quote a recent writer: "In these days of butter not traceable to the cow, of wine innocent of the grape, of beer estranged from hops and malt, of coffee-berries made in a mold and not grown on a bush, of honey not made in a beehive but in a factory, and a thousand and one audacious frauds, we consume one hundred million dollars' worth of fraudulently prepared food

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a year. Fraud has been officially detected in more than three thousand samples of food. From the cheapest and most ordinary article of diet, such as French sardines (caught off the coast of Maine) and canned salmon (with apologies to the swordfish) to such costly delicacies as Russian caviare (collected in Delaware Bay) and imported Lucca oil (from the cotton fields of Georgia), there is imposition." But Americans do not object to this very seriously, perhaps on account of a trait of character portrayed by Dr. Wiley before the Franklin Institute. He spoke as follows: "Barnum made a colossal fortune by acting on the principle that Americans liked to be humbugged. There is something soothingly seductive in being led to the circus by lurid posters showing unattainable attitudes of impossible monsters. . This attractiveness is increased by the knowledge that, like the limited express, it implies an extra charge. Were the feats of legerdmain of the mystic Herman actual performances of supernatural powers, they would lose for us half of their charm. To be cheated, fooled, bamboozled, cajoled, deceived, pettifogged, demagogued, hypnotized, manicured and chiropodized are privileges dear to us all. Woe be to that paternalism in government which shall attempt to deprive us of these inalienable rights."

Notwithstanding that food adulteration has caused a good deal of discussion and legislation throughout our land, there is considerable suspicion that it is much ado about nothing. Sooner or later the public will realize the tremendous extent of the fraudulent practices which are in operation. Not only is there danger to the life and health of the consumer, but honest industry is seriously injured. For many years a Pure Food Bill has been before Congress, but so far it has failed to pass. Most of the states, however, have laws which are applicable within their borders. These laws are based upon the English Food and Drug Act, which became a law in 1875. Last November Secretary Wilson, of the Department of Agriculture, approved and proclaimed the Official Food Standards, which had just been formulated by the United States Food

Standard Commission and a committee of the National Association of Pure Food Commissions. It is no simple matter to say what the standard of any particular food shall be, and this recent action only partially covers the ground. The standards consist of definitions and chemical limits, and embrace meat and its products, milk and its products, sugar and its related substances, spices, cocoa and cocoa products. It is hoped that this work will be completed within two years.

The adulteration of food is not a sin of modern times. In London, eighty-five years ago, grocers sold tea made of thorn leaves, dried on copper and colored with logwood and verdigris. Milk was largely made of chalk and water, and sugar was mixed with sand. Only a few years ago a member of my family while in London returned to a grocer some sugar which only partly dissolved in water. The grocer appeared horrified and made the exchange with remarkable rapidity. In the United States the granulated white sugar is as pure as the manufacturer can make it.

The demand for pure food becomes more and more insistent each year, as realization grows of the far-reaching extent of adulteration. A recent bulletin of the North Carolina Board of health reveals how extensively food is now adulterated. The report says that 29 per cent of the vinegar examined was untrue to name; 33 per cent. of the honey was adulterated; 37.5 per cent. of the jellies and jams, and every single sample of apple butter, catsup, and sauces. As I have already said, most of the States have adopted pure food laws, and an immense amount of good has been accomplished through them. Each State has a Food Commission, which keeps a watchful eye upon every variety of food sold within the boundaries of the State. Samples are bought in the open market and carefully analyzed by the chemist of the Commission. Where adulteration is found the violator is prosecuted, and prosecutions are usually successful. In Ohio, during 1901, there were 252 prosecutions. The jury disagreed in only seven cases and there were only nine acquittals. It is interesting

also to note the decrease in adulteration. In Massachusetts in 1883 the percentage of samples of adulterated milk was 83. This fell to 28 in 1900. The percentage of adulterations of foods dropped from 31 per cent. to 14.

Milk is most liable to fraud of all the different kinds of food, because the chief adulterant is water, which costs nothing. In Massachusetts three-fifths of the entire appropriation is devoted to the inspection of milk and its allied products, butter and cheese. In the city we are more apt to be confronted with blue milk than in the country. The law in most States requires the presence of twelve parts of solid matter, since the natural product of the cow does not contain less than this, though it may contain much more. The cream rises in a cow's udder the same as if in a milk-pan, and, unless the cow has violently exercised just before milking, the first milk is less rich in butter fat, and this, by some, is sold to the consumer. The last of the milk, called the strippings, is nearly pure cream. The milkman is apt to keep this for his own private butter-making.

Owing to the fact that milk is such a splendid medium for the growth of all kinds of bacteria, which bring about its decomposition, it is an exceedingly common practice for the milk dealer to add some antiseptic, especially formaldehyde, so that it will keep in hot weather and may be transported long distances. On account of the physiological action of formaldehyde it is a menace to the health and its use in milk should be condemned. But this form of adulteration is dangerous from another standpoint: it becomes a substitute for cleanliness and sanitary precautions, which are so essential to the healthfulness of milk. The requirement of cleanliness is appreciated by the modern progressive dairy, which is a model of purity.

In Connecticut the collection of milk samples is made by agents, who are provided with bicycles carrying in the frame a case containing eighteen cans of a half-pint capacity each. The construction is such that one can may be removed with-

out disturbing the others. Between four and seven o'clock in the morning the agent rides from street to street and buys a pint of milk from every milkman whom he meets, without making known the object of his errand. He notes the name of the milkman or of his dairy given on the wagon.

Eggs, of course, cannot be adulterated, but they may be of varying quality, and now substitutes for them are being manufactured. The reasons for this are that eggs are high priced in winter, while in summer they deteriorate too rapidly. On the Boston market one has the privilege of buying eggs of different ages—"strictly fresh eggs," "fresh eggs," and "eggs." An egg may be preserved by evaporating its contents down to the solid state. By maintaining a low temperature, the water, which is the largest constituent, is driven off. This preparation is called La Mont's crystallized eggs. It is an important product, for in one year alone 100,000 pounds, equivalent to 4,800,000 eggs, were shipped to South African miners. In New York they are now manufacturing an egg substitute, called "ovine." It is said to "take the place of fresh eggs in baking." Analysis, however, shows that it resembles the white of an egg in composition, and not the whole egg.

Coffee offers a good field for the fraudulent operations of the manipulator. The coffee berry is imitated not only in the green state, but also in the roasted condition. There are more than six firms in this country regularly engaged in the manufacture of coffee-bean making machinery. Bogus berries are ground out by the ton, and they are better looking than those that grow on the bush. A paste is made of chicory, starch, pea meal, caramel, and molasses, molded into the proper shape and dried. The pure-food laws have had a very beneficial influence upon coffee adulteration. In one State the percentage of adulterated samples fell in two years from 63 to 25. The adulterants of ground coffee are peas, chicory, wheat rye, and bean hulls. So-called coffee compoundr are mixtures of coffee with other substances, such as cereals. Sometimes

the packages are properly labeled, and again they are not.

Another indispensable beverage is tea. The extent of its use is indicated by the statement that in a recent year ninety-four million pounds were imported into the United States. Tea is adulterated with soapstone, gypsum, iron dust, and sand; also with lie tea, the trade name of a mixture made up of tea dust and other matters made into lumps with starch paste and colored. Tea is also mixed with exhausted tea leaves and leaves of the beech, willow, elm, rose, and wistaria. Finally, all of the green tea and a good deal of the black tea is faced or coated to impart a gloss and an attractive color. Prussian blue, indigo, and soapstone are used for green teas, and plumbago or black lead for black teas.

Cocoa and chocolate are making remarkable headway as beverages. Coffee and tea have been objected to on hygienic grounds, and substitutes are being extensively used. Cocoa is more nourishing than any other beverage, and perhaps as sustaining. Cocoa beans are reddish brown in color and resemble lima beans in shape and size. They are first roasted, a chemical change occurring which develops a very desirable flavor. They are next crushed by machinery to separate them from the shells. The broken cotyledons, free from shells, are known as cocoa nibs. These are ground, and the heat of grinding melts the fat which makes up one-half of their weight, and the ground product runs out as a thin paste. This is allowed to cool in molds, and constitutes our unsweetened chocolate. Cocoa is prepared by removing a part of the fat by pressure and reducing the residue to a powder. Cocoa is made inferior by grinding the beans with the shells on. It is adulterated by adding extra shells as well as wheat flour, cornstarch, and sugar, and this is a common practice.

Beneath the beautiful exterior of the soda fountain sit enthroned a host of frauds. We complacently enjoy the beautifully colored drinks with the idea that they are made of natural fruit juices, such as strawberry, cherry, raspberry, and many more. Some dispensers use the real fruit, but very com-

monly the syrup is made by dissolving granulated sugar in water colored and flavored with substances made in a factory and, finally, in some cases, soap bark is added in order to produce a fine foam. The variety of drinks is very extensive, one wholesale house alone offering an assortment of three-hundred and thirty-three syrups. The artificial extracts made to imitate strawberry, raspberry, and certain other fruit juices are especially obnoxious and give rise to indigestion. Coal-tar dyes are used for coloring purposes, especially for the brilliantly colored drinks seen at State fairs and summer resorts. In Minnesota recently it was discovered that an alleged sweet-apple cider came "fresh from a cider-press" to which the juice was delivered by an underground pipe.

The most palatable and costly sugar is maple sugar. It is an important product, about five million pounds annually coming mostly from Vermont, New Hampshire and Ohio. The great metropolis of the West is also noted for its production. A small quantity of the pure article serves to produce large amounts of "maple syrup." To such an extreme is this carried that there is not left even a smell of the real maple. Adulteration is extraordinarily extensive, and it has invaded the maple woods. The reasons are succinctly stated by the Illinois Food Commissioner as follows: "First—It is so easy any one can do it. Second—It is profitable. Third—Adulteration being common, the manufacturer is compelled to follow suit in order to compete in price. Fifth—The production of maple syrup is less than the demand. Sixth—The undoubted demand for a syrup with a slight maple flavor at a less price than the pure product commands. Seventh—The questionable fact that certain varieties of maple (Canada, North Minnesota) yield a syrup of stronger flavor than consumers demand." The adulterants or substitutes for the maple sugar are cane sugar, beet sugar, glucose, and dextrin. To produce the maple flavor extracts of walnuts, butternuts, and corn-cobs are used.

A pure fruit jelly is made entirely from the fruit juice with the addition of cane sugar. The adulterants are numerous

The jellying quality may be imparted by starch paste, gelatin, or agar-agar, a gelatinous material obtained from sea-weed. These, of course, have no taste, but by adding a coloring matter and some flavoring extract we have at once currant jelly, grape jelly, or any kind whatsoever. Glucose is much used for sweetening purposes, although it is less sweet than cane sugar, the ratio of sweetness being about three to five. In one year the Connecticut station found twenty pure jellies and forty-three adulterated, the first being home products, while the adulterated were factory products. Jams also are not always what they seem to be. A sample of strawberry jam recently analyzed in Nebraska was found to consist mostly of pumpkin, tinted with coal-tar dyes, preserved in benzoin, with grass seed thrown in to make the jam look like the real thing.

Honey in the comb probably cannot be adulterated except by the bee itself, which seems to have a monopoly on capping the cells. That the inventive American has made many attempts to produce a machine which would do this work there can be no doubt. Strained honey is readily adulterated, glucose being the usual adulterant. Sometimes only sufficient real honey is added to impart a slight honey flavor. A glass jar of glucose with pieces of honeycomb floating in the liquid makes a beautiful deception and a very profitable one.

Spices afford a very attractive field for the sophisticator. Allspice has been found in some cases to contain as much as 85 per cent. wheat and nut shells. Cayenne is adulterated with corn, wheat, ginger, and a red aniline dye. Cloves may contain wheat, sawdust, charcoal, and factory sweepings. Ginger is adulterated with wheat, rice, and pepper. Mustard is liable to contain mustard hulls, corn, wheat, and rice sometimes to the extent of 90 per cent. Pepper is adulterated with wheat, ginger, pepper shells, olive stones, and buckwheat,

The labeling of food products is a matter of considerable importance, because it is from the label that we usually get our ideas of the character of the goods. Labels are wholly deceptive. Such words as "high quality," "high grade," "ex-

cellent quality," "pure," and "unadulterated," are often found attached to articles of the most worthless character. Various devices are employed to lead the unwary astray. Here is a label:

LEMON EXTRACT

Alcohol, 415.

Aqua, 450.

Oil Lemon, 15.

The resort to the Latin word is a fraud of low order. The extract actually contained more water, less alcohol, and no oil of lemon whatever. On a box of powdered borax put out by a New York house was found the following caution: "Avoid the many spurious imitations of our borax with which the market is flooded, and which can only do harm to those who use them. See that our trade mark is on every package." The chemical examination of this borax showed that every package was seriously adulterated with bicarbonate of soda.

Again on a package of coffee, the statement "Made of pure coffee and cereals" is placed perpendicularly, and the instruction to "Open this end" placed at the opposite end.

The food laboratory in the Bureau of Chemistry, United States Department of Agriculture, is now engaged in investigations of the highest importance. Under Dr. Wiley a squad of men take their meals at the Bureau's laboratory, the food being doctored with borax, salicylic acid, and other substances which are said to be deleterious to health. The experiments are extremely interesting, and the results promise to be important.

In conclusion it may be said that all adulterations are not harmful; in fact, many are actually wholesome. A watchful eye is required to detect the serious abuses, which are all too common, and it is necessary to distinguish between the harmless and harmful frauds. The press is prone to exaggeration -- a practice vividly portrayed by Bob Burdette in the following poem, entitled "A Victim of Delusion:"

Placid I am, content, serene;
I take my slab of gypsum bread,

And chunks of oleomargarine
Upon its tasteless sides I spread,

The egg I eat was never laid
By any cackling feathered hen;
But from the Lord knows what 'tis made
In Newark by unfeathered men.

I wash my simple breakfast down
With fragrant chicory so cheap;
Or with the best black tea in town—
Dried willow-leaves—I calmly sleep.

But if from man's vile arts I flee,
And drink pure water from the pump,
I gulp down infusoriæ
And hideous rotatoriæ
And wriggling polygastricæ
And slimy diatomaceæ
And hard-shelled orphryocercinæ
And double-barrelled kolpodæ
Non-loricated ambroëilæ
And various animalculæ
Of middle, high and low degree;
For nature just beats all creation
In multiplied adulteration.

[By permission of the Outlook Company.]

NOTES ON THE SCUTELLATION OF THE RED
KING SNAKE, *OPHIBOLUS DOLIATUS*
COCCINEUS, SCHLEGEL.

C. S. BRIMLEY.

"Body color scarlet, completely encircled by pairs of black rings, with interspaced white in the young, yellow in the adults: no lateral spots, top of head red, with the first black ring crossing the parietals. The pattern is formed by the obliteration of the lateral portion of the black borders of dorsal spots, and the extension of their transverse portion entirely around the body. The lateral spots have disappeared" (From "A Review of the Genera and species of North American Snakes, North of Mexico," by A. E. Brown, Proc. Acad. Nat. Sci, Phila, Jan. 1901). According to Brown the normal scutellation would seem to be 21 rows of scales, loreal present, one temporal in the first row, the rows of scales occasionally varying to 19, and the loreal sometimes absent, this extreme form being the *Osceola elapsoidea* *B. and G.*

Cope treats the two forms as a distinct species, and gives the scutellation as loreal present, two temporals in first row, and rows of scales 21 for *coccineus*, and loreal absent, one temporal in first row, row of scales 17 or 19 for *elapsoidea*. (Crocodylians, Lizards and Snakes of North America, by E.D. Cope, Report of U. S. Nat. Museum, 1898.)

My experience is that the normal formula is, scales in 19 rows, occasionally 17 or 21, one temporal in first row, occasionally two, and loreal usually present, but sometimes absent on one or both sides.

The specimens that I have examined with reference to some or all of these points are

A. Specimens from Bay St. Louis, Miss.,

No.	Length.	Loreals	Temporals	Scales	Examined
1..	21 inches	...1-1.....	1-1.....	19 ..	Mch. 11.'01
2..	21 "	...1-1.....	1-1.....	19 ..	" " "
3..	8 "	...0-0.....	2-2.....	19 ..	" " "
4..	10 "	...1-1.....	1-1.....	19 ..	" " "
5..	15 "	...1-1.....	1-1.....	19 ..	" 19 "
6..	12 "	...1-1.....	1-1.....	19 ..	" 25 "
8.	240 mm	...1-1.....	1-1.....		alcoholic 3607
9..		...1-1.....	2-1.....	19	" 3654
10..		...1-1.....	2-?.....		" 3055
11..		...1-1.....	1-1.....	19	" 3058
12..		...1-1.....	1-1.....	19	" 3045
14..		...1-1.....	1-1.....	19	" 3057
15..		...1-1.....	1-1.....	19	" 3056
16..		...0-0.....	1-1.....	19	" 3044

B. Specimens from Raleigh, N. C.

7..		...0-0.....	1-1.....	19 ..	Apl. 26,'01
13..		...1-.....	2-2.....	21	alcoholic 3059
19..		...0-0.....			May 10'05
20.	180 mm	...1-1.....		19	alcoholic 5524
21.	150 "	...1-?.....	1-1.....	19	" 5523
22.	450 "	...0-?.....	2-1.....	21	" 3682
23.	240 "	...0-0.....	0-0.....	19	" 3683

C. Specimens from Florida.

18	from Orlando.	0-0.....	1-1.....	17	" 2330
17	from Tarpon Sp	1-1.....	1-1.....	17	" 2488

NOTES ON THE ABOVE SPECIMENS,

No. 2 has the nuchal yellow collar divided in the center by a longitudinal bar of black.

10 has both red and white rings more or less interrupted on the belly by black.

13 has the adjacent black rings uniting on the belly, enclosing the red dorsal spots.

20 has the white rings mainly interrupted more or less on the belly by black blotches, while the red rings are uninterrupted.

21 is typical coccineus, in color, but has the loreal reduced on one side to a small triangular plate at the junction of the prefrontal, nasal, and 1st and 2nd upper labials.

22 is nearly typical cocineus, but has black spots on the belly opposite the white rings. Several of the head plates peculiar. The loreal is absent on one side and represented on the other by a triangular plate cut off front of prefrontal and extending to the labials.

23 has red spots closed by a partially divided black tract on middle line of belly. Black spots on belly opposite the white rings are present on latter half of belly only. Sixth upper labial on each side reaches to the parietals and suppresses the temporals.

SUMMARY. The Mississippi specimens all have 19 rows of scales, except two not examined for that point, twelve of them have the loreal present on both sides of the head, and two of them have it absent on both sides: eleven have one temporal in the front row on both sides, one has two temporals on both sides, one has one temporal on one side and two on the other, and the last has two temporals on one side and the scutellation could not be made out on the other.

Of the Raleigh specimens four have 19 rows of scales, and two have 21, while a seventh was not examined for that point. Two have a loreal on both sides, three have the loreal absent on both sides, while of the remaining two, one has loreal present on one side and represented by an abnormal plate on the other, and the other has loreal absent on one side and represented by an abnormal plate on the other. As to the temporals two specimens have one in first row on each side

and two more have two on each side, a fifth has two on one side and one on the other, while the sixth has the temporals completely absent. The seventh was not examined on that point.

The obvious conclusions are that the normal scutellation is 19 rows of scales, loreal present, and one temporal present in the first row. The most curious feature is the large percentage of Raleigh specimens with the loreal absent or abnormal on one or both sides, a feature we would naturally expect in the more southern specimens rather than in the northernmost of those examined.

NOTES ON THE FOOD AND FEEDING HABITS OF SOME AMERICAN REPTILES.

C. S. BRIMLEY.

The following notes are from personal observations made during the past ten or twelve years on various reptiles, both wild and in captivity.

Taking the snakes first, their method of swallowing their prey deserves attention, and to understand this it must be remembered that both the upper and lower jaws and the teeth-bearing bones of the palate are united by ligaments only, thus rendering the mouth capable of very great dilation. Furthermore, any ordinary harmless snake has four rows of sharp backwards pointing teeth in the upper jaw and two rows in the lower.

Now, when a colubrine snake, a Spreading Adder (*Heterodon platyrhinus*) for instance, seizes its prey, in this species always a toad, it at once commences, so soon as it has a good hold, to work one side of the jaws forward over the animal with a chewing motion; then when it has worked that side as far as possible it takes a firm hold with that side and works the other side forward over the animal alternately until it is well within the mouth, when it is pushed down into the stomach by the muscular contraction of the body; the snake in fact literally glides over its prey, after it is once safely inside, often pushing it down by crawling forward with its side pressed against some hard object.

In the case of *Coluber obsoletus* or any other of the chicken snakes swallowing a hen's egg, an apparently impossible feat when one sees the snake and egg side by side, the modus ope-

randi is exactly the same, except that the snake has to get the egg in a position where he can push his mouth over it without it rolling away, in the corner of a box for instance. The egg so far as I can make out passes into the snake's stomach whole and unbroken and the shell being dissolved by the digestive fluids, its contents are released and digested.

Those harmless snakes which have but little constricting power, such as the various species of Water Snake, the Garter Snakes, Green Snake, and Spreading Adder, simply catch their prey and swallow it alive and whole without further dallying. The Snakes of the genera *Ophibolus* (*Lampropeltis*,) *Pityophis*, *Coluber* (*Callopeltis*,) *Bascanion* and *Spilotes*, commonly known as King Snakes, Bull Snakes, Chicken Snakes, Black Snakes, Coachwhips, and Gopher Snakes have however very considerable constricting power as may be easily proved by allowing a good sized specimen of any of these genera to coil itself round ones wrist, but to what extent they habitually kill their prey by this means I do not know. The common black King Snake with white rings whose food consists of rats, mice and other snakes kills the latter in its coils before swallowing them, but how it treats the former I do not know. On one occasion I had placed a King Snake, possibly some 18 inches or 2 feet long in a box with a number of other snakes all considerably larger than itself, almost immediately it glided up to a large Black Snake and seizing it by the head wrapped itself in a tight spiral coil round the forepart of the latter's body. The Black snake however thrashed about so violently that the King had to let go, and when the latter again attempted to seize him the Black Snake struck him on the head which cooled off his ardor and there was no further trouble between them. On another occasion I placed a large King Snake in a box with a smaller Black Snake, and the former seized the latter by the head and crushed the life out of him in his coils, but releasing the Black Snake's body little by little as he swallowed it. I once saw a Chicken Snake, I think it was the striped southern species *Coluber quadrivittatus*, kill a young fledgling bird

which I had placed in the same box with it crushing it to death in a U-shaped fold of the snake's body. These snakes all swallow their food in precisely the same way as the Spreading Adder, which is the usual method with snakes. The constricting power of the genera *Ophibolus* and *Coluber* is much greater than those of the genus *Bascanion* (Black Snakes and Coachwhips).

Of the amount of food consumed by snakes I have four records. The first is that of a poisonous snake, a Copperhead (*Ancistrodon contortrix*) an average sized adult, which grew fat and improved greatly on the following diet: 1897, Aug 7, small bird; Aug 12, ditto; Aug 19, ditto; Aug 25, ditto; Aug 30, 1 mouse, Sep 10, 14, and 19, one small Cotton Rat on each date. In 44 days it ate nine times, never eating more than one small bird or animal on any one day, though more than that number were sometimes offered it. All the specimens were dead. The snake improved in girth and color and some chafed places on its neck entirely disappeared.

The second record is that of a 33 inch Rat Snake or Spotted Racer (*Coluber guttatus*) which did well on the following rations:—1897, July 29, one bat; Aug. 7, one small bird; Aug. 10, 12, 17, and 19, one bat on each date; Aug. 23, one small bird; Aug. 30, one bat; Sep. 14, one mouse; Sep. 20, one shrew. In 54 days it ate ten times, in 31 days it ate seven times.

The third and fourth records are of the Spreading Adders, one of which ate ten toads from Aug 6 to Sep 11, 1897 (ten toads in 86 days,) and another twelve toads from Aug 6 to Sep 9, 1897 (twelve toads in 34 days).

The food of the various species of snake that have come under my notice is as follows, so far as my observations go,—

Spreading Adder (*Heterodon platyrhinus*): toads (*Bufo*) only.

Water Snake (*Natrix sipedon*): fish, toads.

Garter Snakes (*Eutaenia sirtalis*): toads.

Ribbon Snake (*Eutaenia saurita*): small frogs, small salamanders.

Chicken Snakes (*Coluber obsoletus*, *C. o.*, *confinis*, *C. o.*,

lindheimeri, *C. quadrivittatus*): rats, mice, small birds up to size of quail, young birds, bird's eggs, hen's eggs.

The Bull Snakes (*Pityophis sayi* and *P. melanoleucus*) same food as the Colubers.

Spotted Racer (*Coluber guttatus*) has not been observed to eat hen's eggs, but otherwise its food seems to be much the same as the other Colubers, although I think it shows a much greater preference for rats and mice: and the same remarks apply so far as my experience goes, also to the Black Snake (*Bascanian constrictor*) and the Coachwhip (*Bascanian flagellum*).

King Snake (*Ophibolus getulus*): rats, mice and other snakes.

Brown King Snake (*Ophibolus rhomboamaculatus*): rats, mice and lizards.

Red King Snake (*Ophibolus coccineus*): lizards, (*Eumeces* and *Liolepisma*).

Green Snake (*Cyclophis aestivus*): large insects such as larval katydids and the caterpillars of the Silver-spotted Skipper.

Brown Snake (*Haldea striatula*): earthworms.

With regard to the food of lizards, I cannot say much. The smaller species however eat insects of various kinds, the common rusty Fence Lizard (*Sceloporus undulatus*), and the Green Lizard (*Anolis principalis*), commonly though erroneously known as "Chameleon," having been observed in confinement to eat house flies, young grasshoppers, and small butterflies, while the Bluetailed Lizard (*Eumeces fasciatus*) commonly known as "Scorpion" in the South, has been observed to eat house flies, butterflies, small carabid beetles, earthworms, cockroaches and large, smooth caterpillars, but bright colored butterflies were not liked. The so-called Glass or Joint Snake (*Ophisaurus ventralis*) has been observed to eat Katydids, large Bird Grasshopper (*Schistocera americanum*) and large butterflies such as the swallowtails. The other legless lizard of the eastern United States, the curious Flor-

ida Blindworm (*Rhineura floridana*) which superficially looks more like an earthworm than a lizard, apparently eats earthworms, as in 1900 I kept some for several months and used to put earthworms in the box of earth in which they were kept, and the said worms uniformly disappeared without leaving any trace behind.

Only one other lizard has come under my notice in captivity, viz.: the big Gila Monster (*Heloderma suspectum*) of Arizona and this in captivity seems to confine itself mainly, if not entirely to hens' eggs, which when broken on a plate are lapped up by its broad fleshy tongue. My notes on this species are as follows:—1898, July 9, one large one received, drank water; July 11, ate 3 eggs; July 12, ate two; ate nothing from July 13, when he ate one egg, till July 22, when he ate another, not in the meanwhile eating eggs when offered to him. From July 23 to Oct 25 he ate 25 eggs, eating one every three or four days and fattened on the diet. 1899, three *Heloderma* received May 2, sent off May 9, ate 17 eggs in 8 days. 1899, three more received May 23, sent off May 30, ate 21 eggs in 8 days.

The Testudinata, of which the different species are indiscriminately known as turtles, tortoises, and terrapines the last name being in the South applied to nearly all species except the Snapping Turtle, comprise both omnivorous, carnivorous, and herbivorous species.

The Gopher of Florida (*Xerobates polohemus*) is a good example of the first group, feeding only on succulent plants of various kinds, those I had showing only most partiality to nut-grass, although they would also eat corn leaves, zinnia leaves and stems, sowthistles (*Sonchus*) and also apple peel and pieces of apple. Several of the aquatic species are also mainly herbivorous, especially the Painted Turtle, *Chrysemys picta*, which in 1900 ate greedily of cabbage leaves, although they also have been observed to eat raw flesh, chicken offal, corn bread, pieces of watermelon and canteloupe. They usually drag their food into the water and eat it with the head under

water. On July 16, 1900, however, I saw one eating a piece of canteloupe on land without taking it into the water. *Pseudemys concinna*, the large smooth terrapin of our rivers, is also apparently herbivorous, at least I have never detected one in the act of eating flesh. Our other species of *Pseudemys*, however, the Rough Terrapin (*Pseudemys scripta*) is an omnivorous feeder eating raw flesh, ripe fruit, and the leaves of succulent plants. Like the two preceding it eats its food, mainly at least, under water. The terrapins of the genus *Chelopus* seem to be more omnivorous than *Chrysemys* or rather to show a less decided preference for vegetable food. The Speckled Terrapin (*Chelopus guttatus*) has been observed to eat apple, pieces of watermelon, sonchus leaves, dead snakes, fish scraps, etc, usually taking its food into the water to eat it; the other two species of the genus, however, (*Chelopus insculptus* and *C. muhlenbergii*) seem to eat their food mainly on land, but are however more terrestrial than *C. guttatus* which is in its turn less aquatic than *Chrysemys picta*.

Chrysemys picta The Box Tortoises or Highland Terrapins of the genus *Terrapene* (Cistudo) which are terrestrial and not aquatic have been seen to eat raw flesh, dead birds, ripe and unripe fruit such as apple, tomato, watermelon, canteloupe, plum and persimmons and also occasionally the leaves of succulent plants. June bugs are also eaten during the period of their abundance. Their usual method of eating is to stretch the head forward towards their food, seize a piece in the jaws, and then jerk or pull the head backward so as to tear or cut the piece away, the forefeet being usually braced against the food or placed on it, while the portion to be swallowed is torn away. The morsel of food is then crushed sufficiently by the masticating surfaces of the jaws (turtles have no teeth) and swallowed. There is no difference so far as I have been able to observe in the food of the different species of *Terrapene*, and I have had opportunities for observing *T. carolina*, *T. major*, *T. triunguis*, *T. ornata*, and *T. bauri*.

The Mud Turtle (*Kinosternon pennsylvanicum*) is apparently

like the rest of its family carnivorous, never having been observed by me to eat vegetable food. This species and the others of the same genus are the only turtles that cannot support themselves in deep water without something to rest on, and if one is placed in a tub of water where it cannot support itself on something so as to get its head out of the water, will soon become exhausted from its struggles to reach the surface and drown. All our other genera of turtles both aquatic and terrestrial, including the nearly related *Aromochelys* which by the way is thoroughly aquatic, float without any difficulty whatever.

Of our other species of Testudinata I have no observations to record except that a Snapping Turtle in the possession of the State Museum used to eat live toads, dragging them under water to swallow them.

THE SOUTHERN APPALACHIAN FOREST RESERVE.

BY JOSEPH HYDE PRATT.

The forest wealth of North Carolina and Tennessee makes the establishment of a Southern Appalachian Forest Reserve of very great interest to these States; but as these forests affect industries throughout all of the Southern States, and thus affect the industries of the entire country, the establishment of this Forest Reserve is a matter also of national interest and concern. One hundred years ago there was little or no attention given in this country to the method or means by which its forests were cut away; that is, whether they were cut for lumber or ruthlessly destroyed in the clearing of land for agricultural purposes. There was no thought paid to the prevention of forest fires because they were harmful to the forests themselves; and no thought whatever was given to the influence that forests exert on the flow of streams and rivers. At that time there seemed to be a superabundance of lumber for all purposes, the wasteful destruction of which could not then be felt. Forest fires were not considered as doing any particular harm as long as they did not come too near the habitations of men. The streams and rivers always contained plenty of water and for a quarter of a century not enough land was cleared of their forests to demonstrate the effect their removal had upon the water supply.

At the beginning of the 20th century, however, there has been a decided change in the views and ideas regarding the value to a country of its forest resources. Thus, our leading

statesmen and our citizens realize and appreciate not only the commercial value of the perpetuation of our forests, but also the vast influence that these forests exert in the preservation of the water supply of the country. Perhaps their most noticeable influence is in mountainous and hilly countries, which, when covered with abundant forests, prevent the soil from being washed away and by the decay of their leaves form a loam which prevents the waters from running off the surface too rapidly. It is these forest-covered mountains that are extremely valuable because of the effect they have upon water supply and water powers.

By the removal of the forests there is no longer a protection for the soil on the slopes of the mountains and hills except that produced artificially in the form of ditches, etc. There is no longer a layer or bed of leaves to act as an absorbent for the water and a preventive to its evaporation and it runs off for the most part as fast as it falls, causing high freshets and floods and periods of extreme low water; causing the streams and rivers to be higher at times of floods but very much lower the greater part of the time than they were before the removal of these forests. This is well illustrated at the present time in many parts of eastern United States where many of the rivers are not navigable to the extent that they formerly were and many of them are a constant expense to the government in keeping them open to navigation due to low water. While a great deal of harm has already been done in this way, a still greater harm will be done if the remaining forests are not protected. It is not only the navigation of the streams and rivers that is hurt by the removal of the forests but also the water supply for our cities and towns. Many of our largest cities are already beginning to find some difficulty in storing a sufficient supply of water for their use.

This preservation of the forests means also the maintenance of the water powers, which, if reduced or destroyed, will seriously injure many of our manufacturing interests.

These defects in the water supply are not due to the lack of rain but to the removal of the natural agencies that nature has provided for the storing of this water which has resulted from the removal of the forests. Again, these defects are not due to any considerable extent to the clearing of land for farming purposes for the farmer must of necessity protect the soil from being washed away and the only loss to the water supply that he would cause would be the greater evaporation to which it would be exposed. They are, however, due to the wasteful and destructive removal of the forests by the lumber companies who leave large tracts of land stripped in some cases of every vestige of a tree.

The present method of cutting timber and the subsequent forest fires is causing a scarcity of lumber, especially of the hard woods, and there are now but few sections in this country where virgin forests of this character are to be found. This total destruction of a forest in lumbering is not necessary but it is a wasteful destruction of property, and a forest-covered area which should be a constant source of revenue, becomes in the end waste land and in many cases an impoverished, barren tract.

This scarcity of hard woods can be remedied by the application of practical forestry which would be adopted in any forest reserve established in the Southern Appalachian Mountains and is now being practiced in the forest reserves of the western part of this country. There is little or no doubt but that the forests of the Southern Appalachian mountains can, by systematic and conservative measures, be made to yield profitable returns to the State and country. The forests of North Carolina and Tennessee are, and have for many years, been one of the chief resources of revenue to the people of these States and thus their preservation and perpetuation means a constant source of revenue to these States.

Thus the two main and vital reasons for forest reserves are first, the protection of the water supply of our streams and

ivers; and second, the protection of our supplies of lumber, especially the hard woods.

The region that is to comprise the proposed Appalachian Forest Reserve lies for the most part in Western North Carolina and eastern Tennessee, with smaller areas in southwestern Virginia, northeastern Georgia and northwestern South Carolina. The slopes of the mountains in this region are the sources of many large rivers, as the Tennessee, the Savannah, the Broad and the Catawba. The water-power and navigation of these rivers are seriously affected by the removal of the forests in the mountainous districts as is also the water supply for the towns and cities in the vicinity of the mountains and of these rivers. This southern section of the United States has not been subjected to glacial action as the northern States have and there are, therefore, no glacial drifts in this region to act as storage reservoirs for water. Thus, in the removal of the forests we are practically removing all the natural resources for storing water.

In speaking of forest reserves and particularly of the proposed Southern Appalachian Reserve, President Roosevelt in his address at Raleigh, N. C., October 20, 1905, pointed out how vital the preservation of the forests is to the welfare of every country and that the upper altitudes of the forested mountains are most valuable to the nation as a whole, not only on account of their commercial value as supplies of lumber, but especially because of their effects upon the water supply. He further said: "Neither state or nation can afford to turn these mountains over to the unrestrained greed of those who would exploit them at the expense of the future. We cannot afford to wait longer before assuming control, in the interest of the public, of these forests; for if we do wait, the vested interests of private parties in them may become so strongly intrenched that it may be a most expensive task to oust them. If the Eastern States are wise, then from the Bay of Fundy to the Gulf we will see, within the next few years, a policy set on foot similar to that so fortunately car-

ried out in the high Sierras of the west by the national government. All the higher Appalachians should be reserved, either by the states or by the nation. I much prefer that they should be put under national control, but it is a mere truism to say that they will not be reserved either by the states or by the nation unless you people of the South show a strong interest therein."

North Carolina, which would give the largest area to the Appalachian Forest Reserve, is unequalled in its variety of hardwoods and conifers by that of any other State or Territory. Throughout the whole area of the State, the great variety of soils and climate has brought together trees from all parts of eastern America so that 24 kinds of oaks are to be found in the State, which is three more than occur in any State to the north of this one, and two more than are to be found in any State to the south; of the nine kinds of hickories known to occur in the United States, eight have been found in North Carolina; here are all six maples of the eastern United States; all the lindens; all six of the American magnolias; three of the birches; eight pines out of eleven; both species of hemlock and balsam-fir; three elms out of five; six arborescent species of plum and cherry; and three of pyrus (apple).

The bleak and exposed mountain summits, bear forests of trees which there find their southern limit, but extend northward through northern New York and New England to Canada. Such trees are the black spruce (the balsam), striped and spiked maples, mountain sumac, which is really an apple, balsam fir and aspen, all unless sheltered by other trees or by the slopes of the mountain above them, rugged and dwarfed from the cold and constant wind to which they are exposed.

The commercial forest trees are on the slopes of the mountains and in the ravines and valleys. Some of these trees have wide distribution to the north of North Carolina or to the south of it, or in both directions, and some of them are

restricted in their distribution to North Carolina or to the region around the southern Appalachian mountains.

The mossy cup, yellow and shingle oaks, white linden and big shag-bark hickory, prominent trees of the central States, extend as far to the southeast as central North Carolina; while trees of the north, like hemlock, sugar or hard maple, northern red oak, cherry, birch and white pine, and of the northeast, like the pignut hickory, chestnut, northern pitch pine and balsam enter more or less largely into the composition of the forests of the western parts of the State.

Many trees of wide distribution, and among them some of the most valuable, extend from this State in all directions, the white, post, black, scarlet and Spanish oaks, the red and white maples, the white hickory and brown heart and shag-bark hickories, short-leaf pine, yellow poplar, red cedar, black cherry, and black walnut. The cypress, water and willow oaks, downy poplar, swamp-white oak (*Q. Michauxii*, Nutt.) southern elm, and planer trees are trees having a great range to the south and southwest. A few trees are found only in this State, or extend but a short distance beyond its boundaries, the yellow-wood, the large-leaved umbrella tree, the Carolina hemlock, the clammy locust, the last being entirely confined to this State.

Altogether there are 153 kinds of woody plants, which form a simple upright stem and attaining arborescent proportions growing naturally within the State; and of these over seventy are trees of the first size, and fifty-seven are trees of great economic value. Fourteen of these are known to attain in this State a height of over 100 feet, three of them a height of over 140 feet, sixteen of them reach in this State diameters of five feet or over; and five reach diameters of seven feet or over.

The areas of the other States included in the proposed Forest Reserve also contain a large variety of trees and thus this region contains the greatest variety of hard woods to be

found anywhere on the American Continent for it is here that there is an intermingling of the sylvia of the north and south. Here trees that are common to New England are found in close proximity to those that are common to the more Southern States. Here is the largest area of virgin forests to be found in the Southern Appalachian region. Here are trees from five to ten feet in diameter which often tower to a height of 140 feet. The destruction of such a forest would be an almost irreparable loss, for once destroyed it would take generations for its restoration, with a great probability of failure; and then again the chances are that it would not be attempted.

These areas of timber are being rapidly acquired by those whose one object is to make the most profit possible out of them at the present time with no thought for the future. Many of the older countries, as Germany and England, have suffered to such an extent by the destruction of their forests that they, especially Germany, have begun already to take measures to preserve their forests and to make them such that they will be a constant source of lumber, and Germany has shown that by her system these forest reserves become self-supporting. England has become so depleted of her timber that she is obliged to import the greater part of her lumber.

The only remedy for the protection and preservation of our forests is for the National Government to obtain possession of them and to care for them by the application of scientific methods.

Such a forest reserve under the management of trained forest experts will demonstrate how these forests can be perpetuated and at the same time be made to pay. Such an example will have an influence on the several States and individuals by encouraging them to practice forestry and to use those lands for growing timber that are more suited for this purpose than for farming industries. It will be an object lea-

son and a laboratory for those studying or interested in forestry.

The acquirement of this land by the national government for a forest reserve will not be setting a precedent for, "nearly 50,000,000 of acres of forest covered lands have been set aside (in the Western States) as National Forest Reserves and parks for the purposes of perpetuating a timber supply in the Western States and territories and for preserving forever the sources of their more important streams." Thus what is now proposed is not new either in principle or practice. There are a number of reasons that can be given why this should be a National Forest Reserve. First, the problems and dangers that it is intended to meet are national; second, this tract of land lies in several States and the streams that rise in them flow through many States and it would be difficult, even if possible, for these States to control and operate such a reserve successfully; third, these States are not so situated financially that they could even make the attempt to carry out this plan. Thus if the forest reserve such as is contemplated is established it must be done by the National Government. The several States have conferred upon Congress the necessary authority to acquire land within their respective borders. These lands can at the present time be purchased at a very reasonable price; but they are increasing in value from year to year. While there are these fifty millions of acres in National Forest Reserves and Parks in the West there is not a single National Forest Reserve in the East. (There are a few State Reserves.)

The withdrawal of this large amount of land and putting it into the hands of the Government will not prevent the development of its other resources (mineral and agricultural) for these can be developed as fast as capital desires but under the judicial guidance of the Government and it is possible for large industries to become established in them.

Besides being a forest reservation, this tract of land will also be a large National Park, though this is a secondary

consideration. It will be a National Park that will contain scenery of rare natural beauty and will contain the highest mountains east of the Rocky Mountains and which are covered with trees and shrubs to their summits. The healthfulness of this region is already known throughout the country and this and the climatic conditions are very favorable to a Park.

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"PHYSIOLOGICAL ECONOMY IN NUTRITION"—
Chittenden.

DR. ISAAC H. MANNING.

There cannot be a more generally interesting subject than Physiological Economy in Nutrition. The habit of excessive indulgence at the table is still very common and habitual over-eating is practically universal. The pernicious effects of the former are often immediate and convincing, while the harmful effects of the latter, though insidious, are none the less certain. The restraint of one's appetite, after generations of hereditary and years of acquired indulgence, and its restriction to a diet nearly approaching the actual needs of the body, requires a degree of self control and watchfulness that few of us possess, and yet it needs no argument to convince us that every ounce in excess of this entails a wasteful expenditure of body energy, an unnecessary and harmful burden on the body machinery, and places both our mental and physical effectiveness on a lower plane. The mental and physical hebetude following a heavy meal is a common experience and so often has disease been traceable to disturbances

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in nutrition that it is a medical axiom that the "majority of diseases of mankind are due to or are connected with perversions of nutrition." The habit of undereating is none the less pernicious, but, if we are to accept Dr. Chittenden's standards, it is so rare as to demand little consideration.

A diet just sufficient to maintain the highest mental and physical effectiveness, with due consideration for a capricious, somewhat fanciful appetite is the ideal. An effort to establish such a dietetic minimum, of more or less general application, through experiment, has resulted in the formulation of dietetic standards by Voit, Ranke, Hoppe-Seyler, and others, all agreeing in the main that the average adult doing an ordinary amount of work requires something more than 100 grams (3 to 4 oz.) Proteids (the chief constituent of meat), 250 grams (9-10 oz.) Carbohydrates (the chief constituents of cereals), and 100 grams (3-4 oz.) fat; which, together, should have a heat value of about 3,000 heat units (the large calorie). On such a diet it has been found that the individual could maintain a nutritive balance, neither gaining nor losing in weight. These standards have been generally adopted and an analysis of the average diet of soldiers and laborers of different nationalities, as well as other groups of men, have shown them to be rather more than less. But from time to time individual experience and experiment have suggested that they were too high and should be subjected to a critical review and revision. With this object in view, Dr. Chittenden, of Yale University, began his investigation, the results of which have been published in book form under the well chosen title of *Physiological Economy in Nutrition* (Stokes & Co., New York).

Among the striking features of the book is the prominence given the proteid constituents of our diets and his conclusions will be disappointing to the average American who is proverbially a heavy meat-eater and to the athlete who often thinks his success depends upon the number of pounds of meat he can consume. The proteids have been recognized as

the basic constituents of all bioplasm (living substance) and for its repair and growth they must form the most important, though not necessarily the most abundant constituent of our diets, for it has been demonstrated over and over again that one cannot maintain a healthy condition without proteids in one form or another. This has been perhaps the strongest argument with the trainer who wishes to encourage the growth of muscles, notwithstanding the easily proved fact that muscular exercise does not increase the use of proteid matter. Dr. Chittenden calls attention to the fact that an excessive proteid diet produces more strain than any other. They are difficult to digest, difficult to assimilate, and the waste is difficult to eliminate, taxing especially the liver and kidneys. Then again, among the innumerable products of proteid digestion, there are formed many more or less poisonous compounds which act deleteriously on the nervous, muscular, and circulatory systems. Hence an excess of proteids is especially to be avoided. The fat and carbohydrates—especially the latter—are ultimately oxidized to CO_2 and H_2O , and the elimination of the excess does not entail so a great hardship. This, however, does not warrant an excessive indulgence.

An ideal diet, then, should contain just sufficient proteid to make good the wear and tear of the body machinery and to provide for a legitimate growth and, in addition, sufficient carbohydrate (especially) and fat to furnish the body energy; a little meat and the rest vegetable matter. The chief object of the research is to determine the minimum amount of proteid necessary to maintain a proteid balance, with an adequate amount of fats and carbohydrates, for it has been shown that, in the absence of the latter, the proteids will be utilized directly for the production of body energy—a misappropriation—and the proteid diet correspondingly high.

The index to the amount of proteid digested in the body is the amount of nitrogen excreted in the urine during a corresponding period of time. To this is added the amount

of undigested nitrogen and the sum should be equal to the total nitrogen taken in with the food. Where such is the case the individual is said to be in nitrogen balance—the intake is equal to the outgo. If, however, the income is less than the outgo, the individual is accumulating nitrogen as proteid or its by-products. In neither case is one in nitrogen balance. It must be remembered, however, that there may be a nitrogen balance on an excessive proteid diet—so elastic is the assimilating and eliminating power of the body. But it would seem that on a minimum proteid diet this method would give us control of the process.

Different individuals—differing in size, weight, habits, and occupation—require a slightly different amount of proteid, and in order to eliminate this personal equation as far as possible and to make the dietetic standard of general application, it was necessary to experiment upon a number of individuals. In this investigation there was a liberal choice. Among those experimented upon we find professional men, teachers, students, athletes, and soldiers (a squad being detailed from the U. S. Army Hospital corps)—representing a variety of individuals engaged more or less actively in mental and physical exercises.

In previous nutrition experiments the period of time covered by the experiment has been too short to warrant safe conclusions. In these, however, the individuals were under experimental observation for periods of six and nine months, which would seem amply sufficient to determine whether the individual can be maintained indefinitely in nutritive balance with full mental and physical vigor on a given diet. In this respect the investigation is superior to those previously reported and warrants a greater degree of confidence in the conclusions.

The plan of the investigation was exceedingly well thought out and faithfully executed. For two weeks previous to the curtailing of the diet, and while the individual was still living on his accustomed diet, daily determinations of the total

nitrogen excreted in the urine were made and its equivalent in proteid recorded. Then there was a gradual withdrawal of the diet—especially the proteid constituents—thus allowing the body to adjust and adapt itself to the change; and this was continued until a nutritive balance (as indicated by a constant body weight and confirmed by balance experiments) was reached. The balance experiments were performed at stated intervals and covered periods of seven days, during which the food was accurately weighed, samples drawn and analyzed, and daily determinations of the nitrogen in the excreta were made and a balance sheet drawn. During the investigation each individual was furnished with a liberal diet list—the composition of the different ingredients being furnished—from which he might select such articles as would gratify his taste, bearing in mind only the general purpose of the experiment. The advantage of this is obvious when we remember that however choice a diet list may be, if it is restricted in variety, it will become distasteful. Systematic records were kept of the body weight, muscular power, and mental vigor, as is customary in gymnasiums and psychological laboratories, to which was added the testimony of the individual as to his general health, physical and mental condition. In some cases periodical blood examinations were made to detect, if possible, any change in its character in consequence of the restricted diet and the results recorded.

The enormous amount of work entailed by such an investigation can only be appreciated by a careful examination of the innumerable tables which contain the results of the quantitative analyses of foods and excretions, blood tests, physical tests, etc., which were systematically made throughout the entire period on each individual. The energy, patience, and perseverance displayed excites one's admiration.

The investigation seems to demonstrate conclusively that Voit's and all previously formulated standards are much too high, especially as regards their proteid constituents. These can be safely reduced 50 or 60 per cent., provided there is an

adequate amount of fats or carbohydrates. The further conclusion seems warranted that it is seldom necessary to increase the heat value of the food beyond 3,000 large calories and in most instances it may be less. This reduction in the diet does not bring us to vegetarianism nor abstinence from meats, but merely to temperance. Nor does it mean the slightest loss in physical or mental vigor or endurance. On the contrary, the records indicate an increase in muscular power and endurance and so far as mental vigor may be tested or judged, this was unimpaired. The improvement in the general health in Dr. Chittenden himself during the nine months in which he was on a restricted diet and among those who independently adopted a similar regime amply justifies the assertion that dietetic temperance conduces not only to one's general health, but must contribute to longevity of life. Nor does it entail any discomfort arising from an unsatisfied appetite after one has become adapted and adjusted to the restriction, and this may, in a measure, be controlled by prolonged chewing of the food, which is a good habit under any circumstances. It may prove interesting to outline Dr. Chittenden's record of himself during the period of experiment, which is not the least interesting one. Previous to the experiment he was living on a diet corresponding approximately to Voit's standard and was eating sufficient proteids to pass about 16 grams N. in his urine per diem. At this time he was 47 years old and weighed about 167 pounds. He gradually reduced his diet until he was passing on an average of only 5.669 grams N. in 24 hours; corresponding to 35.6 grams Proteids—about one-third the amount prescribed by Voit. And while the heat value of his diet fluctuated to some extent, it seldom exceeded 2,000 large calories and was generally below it. In the early weeks he lost slightly in weight reaching 160 pounds, and it then remained constant throughout the experiment. For a time he would eat no breakfast, a light lunch at 1:30 and a heavier dinner at six. This degree of temperance could be reached only after a gradual reduction, but he states that even now

he has no desire to return to his former habits. He succeeded in reducing the Nitrogen in his urine to a greater extent than any one else, but this was probably due to a greater self control, born of his enthusiasm for the investigation. It is interesting to note that Folin in reporting the analysis of the urine of a vegetarian in apparently perfect health as containing a little less than 5 grams Nitrogen, remarks that "no one would be willing to call it normal urine" (the usual interpretation put upon such urine would be an insufficient action of the kidneys).

It is interesting to contrast Dr. Chittenden's record with Stapleton's, a professional athlete and wrestler, who is described as a man of great muscular development and power. At the beginning of the experiment he weighed about 195 pounds, and on his customary diet was excreting an average of 19.7 grams Nitrogen, corresponding to 123 grams metabolized proteids. (Unfortunately the heat value of the diet is not stated, but it was probably large). He succeeded in reducing the Nitrogen excretion to 9 grams in the 24 hours, corresponding to about 57 grams proteids—a reduction of more than one-half—and this on a diet that rarely exceeded 3,000 heat units. In the early weeks, as before, there was a slight reduction in weight until he reached 185 pounds and this remained fairly constant; his total muscular power increased 25 per cent. during the six months, and this, it may be stated, was not due to a change in the character or the amount of exercise. Similar results were recorded of other athletes and the soldiers who were given more or less vigorous gymnasium exercise, and it may be well to call attention again to the conclusion that a heavy meat diet for athletes is unnecessary and irrational.

The results of this classical investigation are of such far reaching importance that they should not only interest the physician, but every one who takes himself seriously and wishes to bring himself to the highest plane of physical and mental effectiveness. The book is thoroughly readable and comprehensible to the average reader.

CORUNDUM AND THE PERIDOTITES OF WEST-
ERN NORTH CAROLINA.
A REVIEW.

JOSEPH HYDE PRATT AND JOSEPH VOLNEY LEWIS.

Under the above title, Volume I of the North Carolina Geological Survey reports has recently appeared. The scope of the work, however, is broader in many ways than this title indicates. It is a volumes of 464 pages and is illustrated by 45 plates and 35 figures in the text. While the report is the result of collaboration, the work has been divided so that, in the main, the mineralogical investigations have been conducted by Dr. Pratt and the petrographical study of associated rocks has been the work of Professor Lewis. The preface states: "To only a limited extent have the authors been able to carry on field work together. The work for the most part has been done at different times, each working independently. Notwithstanding this fact and the somewhat different methods employed, each has been led to essentially the same conclusions in the interpretation of field observations. Especially is this true in regard to the theories of the origin and present relations of both the peridotites and the corundum.

A brief sketch of Geology of the State is given in Chapter I, with a somewhat fuller description of the belt of gneiss, granites and schists, constituting the mountain section of the west, and in which the peridotites and the corundum deposits of the State occur.

Chapter II deals with the peridotites and associated basic magnesian rocks, including four varieties of peridotites, four pyroxenites, four gabbroic rocks, an amphibolite, and three varieties of diorite. These are chiefly well known types, with the exception of the pyroxenite composed of the orthorhombic

pyroxene, enstatite. This rock is somewhat commonly found throughout the region and forms many masses of considerable extent. The name *enstatolite* is proposed for this type, in conformity with the terms bronzitite and hypersthénite. These rocks are discussed in their relations to the belt of similar rocks which extends the whole length of the eastern crystalline belt, from central Alabama through Georgia, South Carolina, North Carolina, Virginia, Maryland, Delaware, Pennsylvania, New Jersey, New York, the New England States, Quebec, and Newfoundland.

Maps are given showing the distribution and relations of these rocks to the crystalline rocks in eastern North America and western North Carolina, besides several detailed maps of various portions of the belt of particular interest. The contoured map of western North Carolina is on scale of eight miles to the inch, with the base printed in three colors, after the manner of the maps of the United States Geological Survey. On this the "Conglomerates, quartzites, slates, etc., chiefly 'Ocoee,' correlated with Cambrian by the U. S. Geological Survey," and the "Gneisses, schists, granites, diorites, and other crystalline rocks of pre-Cambrian age," are clearly represented by tints, while the numerous dikes of peridotites and related rocks and the occurrences of corundum, chromite and asbestos, are shown in bright red.

The petrographic descriptions which constitute Chapter III are illustrated by half-tone reproductions of photomicrographs, showing the mineralogic and structural variations and modes of alteration of the rocks described. Following the general descriptions of these rocks throughout the Appalachian region, the distribution and petrographic characters are given in considerable detail for western North Carolina.

In addition to the numerous facies of primary rocks, secondary types are also described, including those mechanically derived from the primary types, now represented by gneisses, schists and gabbro-diorite, and also a series of hydrous alter-

ation products, including serpentine, steatite, and chloritite (chlorite-rock). The vast majority of occurrences of these basic rocks, while showing more or less alteration, are essentially fresh primary types, especially the pure olivine-rock dunite, which is much the most common. Steatite is pretty widely distributed as an alteration product, but massive serpentine is almost entirely confined to an area extending about 15 miles north and south of the French Broad river. Even in these cases, however, the origin of the serpentine from peridotites of exactly similar character to those found in adjoining regions is very evident.

Chapter IV takes up the modes of alteration and decomposition of the peridotites, and five distinct processes are recognized: 1. Weathering; 2. Serpentinization; 3. Steatitization; 4. Chlorotitization; 5. Amphibolization. The processes of weathering and serpentinization are wellnigh universal, though developed only to a slight extent except in a few localities. Alteration to talc, chlorite and amphibole are much more limited in their manifestations, but have given rise to many important rock masses. The various processes as affecting the peridotites of diverse composition are described minutely.

The long vexed question of the origin of peridotites is taken up in Chapter V. The strong trend of modern thought toward the theory of igneous origin is clearly brought out, and the correctness of this theory is abundantly substantiated by observations in North Carolina. The data presented upon this point are arranged under five heads: 1. Mineralogic characters; 2. Microscopic characters; 3. Gross structures; 4. Modes of occurrence; 5. Relations to the gneisses and schists. This is followed by a discussion of the general petrology of the peridotites and associated rocks in which the conception of genetic unity of the whole series is strongly emphasized.

It is pointed out as a noteworthy fact that many of these rock types are closely associated in almost every occurrence

throughout the crystalline belt of eastern North America. Usually one or another type preponderates in any particular region, but the associations are always essentially the same. Thus the peridotites, particularly dunite, prevail in North Carolina and Quebec, the pyroxenites in Pennsylvania, and the gabbros are very abundant in Delaware and Maryland. In fact the types represented in the various regions are almost identical, and the petrology is closely similar, except in relative abundance of the various types, and in degree of alteration.

In discussing the magnetic relations of the peridotites, anorthosites, amphibolites, etc., two generations of corundum are recognized. The greater part, including all deposits of commercial value, belongs to the first generation, and was formed by the crystallization of the excess of alumina in the original peridotite magma. A very small part, however, occurring in microscopic grains, has been produced by an excess of alumina arising from the corrosion of anorthite by the still molten magnesia magma. This process has produced the sheaths of intermediate minerals which form the *corrosion mantles*, so beautifully developed in some localities, or which, in some cases, entirely replace the anorthite or the olivine, as the case may be, with nest-like aggregates.

Regarding the age of the peridotites, the conclusion of the present writers may be summarized as follows: Sufficient data are not yet available for a satisfactory determination of the age of these rocks, but their intrusion was probably contemporaneous, or practically so, for the whole region from Newfoundland to Alabama. The peridotite belt lies in a region of great disturbance and intense metamorphism. This fact, together with the geological relations to the northward, suggests the hypothesis that the principal period of intrusion was closely associated with the orogenic movements which closed the Lower Silurian (Ordovician) period. The distribution of these rocks may well mark to a great extent the axis

of most intent folding and faulting. The latter Appalachian disturbances, at the close of the Carboniferous, have produced the lamination so often seen in these rocks, and have probably given occasion for later minor intrusions. This hypothesis is not offered as a final answer to the question of age of the peridotites. Much painstaking work yet remains to be done before an entirely satisfactory solution of this problem can be expected.

The chapter closes with a discussion of the relations of the secondary rocks, in which the attempt is made to trace the various laminated and hydrated alteration products back to their original types. Here the question is reached, whether the amphibolites, diorites, hornblende-schists and hornblende gneisses may not themselves have been derived from corresponding pyroxenite types, such as are met with in the Maryland and Delaware gabbro areas. The fact is pointed out that undoubted gabbro-diorites do exist in portions of the belt in North Carolina, and hence it is considered probable that many, if not all of these rocks, as well as similar rocks throughout the region, have had a like origin.

After a discussion of the physical and chemical properties of corundum in Chapter VI, is given a description of the various applications of the mineral in the arts, and an outline of the process of manufacture of the several types of corundum and emery wheels on the market.

Chapter VII deals with the modes of occurrence of corundum. In North Carolina the mineral is known in five types of igneous rock, namely, peridotite, pyroxenite, amphibolite, anorthosite, and pegmatite, in six metamorphic rocks, serpentine, gneiss, mica-schist, amphibole-schist, and chlorite-schist. It is also found in gravel deposits of emery whose relations are undetermined. These modes of occurrence are described in detail, and are compared with similar occurrences, when known, in other parts of the world. The deposits which have been of chief commercial importance in North

Carolina have been associated with peridotites, and to a less extent with pyroxenites and amphibolites. The gravel deposits are of considerable interest on account of the corundum gems (ruby) and associated garnet gems (rhodolite) that have been found in some of them.

With the peridotites the corundum occurs chiefly in "peripheral or border veins" striking along the borders of many of the massive outcrops, and in "interior veins" extending from the borders at greater or less distances toward the center of the peridotite masses. In the pyroxenite and certain of the amphibolite occurrences the mode is similar. In other amphibolites the corundum is irregularly distributed in grains and larger plates and nodules through portions of the rock. Certain small pegmatite dikes accompanying and penetrating both the peridotite and amphibolite, are found also to carry corundum. The corundum-bearing serpentine, amphibolites, and chlorite-schists are simply alterations of some of the foregoing types, with more or less dynamic disturbances and re-arrangement of materials. Corundum-bearing belts of the gneisses and mica-schists, which sometimes pass into quartz-schists, have no apparent or probable relation with the peridotites, although occurring in the same region, and in some cases near the outcrops of these rocks.

The chief localities of corundum-bearing peridotite are in Clay, Macon and Jackson counties, in the southwestern corner of the State, and most of the corundum-bearing gneisses, etc., are also found in the same counties. Certain scattered occurrences of corundum in amphibolite dikes and also in the gneisses are found east of the mountains, particularly in Iredell county.

"Other occurrences of corundum in America" extends the list of corundum-bearing igneous rocks to include granite, syenite, nepheline-syenite, plumasite, norite, andesite, and monchiquite, and adds crystalline limestone to the list of metamorphic corundum-bearing rocks. A brief description

of each of these modes of occurrences is given with references to the literature of those that have been previously described. An additional list of "Modes of occurrence of corundum not found in America" adds to the number of corundum-bearing igneous rocks, kyschtmite, tonalite, gabbro, quartz-porphyry, trachyte, and basalt, besides contact-zones and inclusions in igneous rocks. To the metamorphic list are added corundum-schists and porphyroids and graphite. These are followed in turn by brief descriptions, completing the list to date of all known modes occurrence of corundum throughout the world.

The distribution of corundum is described in Chapter VIII. Like the peridotites, this is treated first with reference to the Appalachian belt as a whole, noting the occurrences in Alabama, Georgia, South Carolina, North Carolina, Pennsylvania, New Jersey, Connecticut and Massachusetts. Corundum in the western part of the country includes descriptions of occurrences thus far known in Montana, Colorado and California. This is followed by a description of the North Carolina localities in detail, arranged by counties, beginning in the southwestern corner of the State. The chapter closes with the description of foreign corundum and emery deposits, including those of Canada, India, Turkey, and the Grecian Archipelago.

Chapter IX deals with the alteration of corundum and its associated minerals in great detail. The list of minerals found associated with corundum in North Carolina includes 62 species, each of which is described, with its mode of occurrence, and its relations to the occurrence of corundum. Many have chemical analyses and crystallographic characters also given. "Minerals associated with corundum not found in North Carolina" adds 12 more to this list, from various American and foreign localities.

The difficult question of the origin of corundum is discussed in Chapter X. This is prefaced by an account of the artificial production of corundum, and the origin of corundum in nature

is introduced by a sketch of the various hypotheses that have been proposed during the last quarter of a century. After a discussion of the field relations and the later experiments in the production of artificial corundum, the conclusion is reached that the corundum was held in solution in the molten magma of the peridotite when it was intruded into the country rocks, and that it separated out among the first minerals segregated as the mass began to cool. The conclusion is also reached that the corundum in the quartz-schists and gneisses is the result of metamorphism of sandstones and shales, some of which were rich in alumina, perhaps in the form of bauxite, which, during metamorphism, crystallized out as corundum.

Chapter XI deals with corundum mining and milling. It is introduced by a historical sketch of corundum mining in the East, followed by a sketch of mining in America. "Suggestions to prospectors" and methods of mining and milling as carried out at various plants, conclude the chapter.

Chapter XII discusses the chromite and other economic minerals of the corundum-peridotite belt. Chromite in promising quantities has been found at a number of the peridotite localities in western North Carolina, particularly in Jackson and Yancey counties. Its origin and relations are discussed and the conclusion reached is essentially the same as for the origin of corundum in peridotites. A discussion of the chemical composition of chromite and its uses, and a description of the chromite localities of the region, with a summary of occurrences in other parts of the world, follow. The distribution and character of asbestos, nickel ores, serpentine, and limonite, minerals which, thus far, are of minor importance in the region, close the chapter.

An appendix, consisting of a bibliography of American peridotites, and corundum and associated minerals, is not complete, perhaps, as regards the whole of North America, but is believed to be practically complete for North Carolina

and the eastern crystalline region in general. There are also many references to foreign literature in foot-notes throughout the work, and the volume is closed with an elaborate index.

Copies of this volume may be had by addressing the North Carolina Geological Survey, Chapel Hill, N. C.

NOTES ON THE GEOLOGY OF CURRITUCK BANKS.

BY COLLIER COBB.

During the past summer (August, 1904) I have made a careful examination of the Currituck Banks from the Virginia line to Kittyhawk Bay and the Kill Devil Hills, studying also the adjoining islands and mainland to the west.

On Knotts Island the Columbia sands form a thin covering from one to three feet in thickness, resting upon clays of Neocene age, not more than ten to twelve feet thick, at several points where I bored with a soil auger. Beneath these clays are the Tertiary shell marls so well known over eastern North Carolina. This shell-rock, as it is called here, occurs at a number of points in Currituck Sound, as I found by sailing pretty well over the entire sound. A somewhat extensive area of this deposit lies near the surface of the water between Church's Island and the Currituck Bank, being about half a mile west of the Whalehead Life Saving Station.

The cruise in the Sound revealed well-marked channels ending against The Banks at the sites of Old Currituck Inlet, New Currituck Inlet, Caffey's Inlet, and the old inlet opposite Colleton Island. The sand-reefs or banks along the North Carolina coast have grown steadily in length from the time of the earliest settlements, until there is now no inlet from Cape Henry to Oregon Inlet. The inlets through the Currituck Banks have been closed up by the steady southward march of the great barchanes or medanos, crescentic sand-dunes, known locally as whaleheads. These dunes are composed of singularly homogeneous blowusands, the horns or cusps of the barchanes pointing to lee-ward, which is almost due South

Following the ocean side of Currituck Banks, one may often see a distinct terrace marking the line between the Columbia sands and the Neocene clays; on stormy days comminuted Tertiary shells are washed up; and quite frequently after a storm one may pick up water-worn shells of *Cardium*, *Anomia*, and *Exogyra*, of which I brought away a score of specimens. These are distinctly Cretaceous forms. *Ostrea* is unknown among these deposits, but oyster shell heaps of recent date are common on the sound side near the southern end of Currituck.

The facts go to show that The Banks are not of such recent origin as is usually supposed, but are of the same age geologically as the adjacent mainland.

On the Atlantic side of this Currituck Bank I found numerous pebbles, some as much as three to four inches in diameter, buried in the upper sands and muds, some well rounded, others sub-angular, and some of these latter even striated. I have collections of exactly similar stones from the beaches of the North Shore of Massachusetts, from Aquidneck Island, and from Martha's Vineyard. There are, however, in my collection from this Currituck beach many fragments of Triassic trap and sandstone, which are not known among the beach pebbles of the other localities.

These pebbles are, almost without exception, unlike any of the stone of the mainland of North Carolina; and both their position and individual characters point to their glacial origin. It is clear that they are the work of the ice sheet of the last glacial period, drifted southward by icebergs which stranded on the Carolina coast. A rather rapid subsidence of the coast is now in progress, the blown sands and the silt, arrested by aquatic vegetation are rapidly filling in the sound side of the Banks, and the water of the Currituck Sound has already become fresh since it has been cut off from direct communication with the sea, the inflowing streams having leached out the salt.

The Great Whaleshead barchane opposite Church's Island

has moved southward three quarters of a mile in twenty years, and the closing up of the sound has been so rapid as to bring about litigation in the courts for the possession of the new made land. The subsidence of the land is so easily seen from beacons and telegraph poles as to be a matter of remark among the least observant of the inhabitants.

Presented October 11, 1904.

THE NEW ORLEANS MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AND THE AMERICAN CHEMICAL SOCIETY.

BY CHAS. H. HERTY

One of the prime objects of the American Association for the Advancement of Science is, as formulated in its Constitution, "by periodical and migratory meetings, to promote intercourse between those who are cultivating science in different parts of America." Following this policy the 35th meeting of the Association was held during Convocation week, Dec. 29th, '05-Jan. 4th, '06 at New Orleans, La., this being the first meeting held in that section of the country. The fact that many of the affiliated societies met at the same time at other points reduced largely the attendance at the New Orleans Meeting, but the joint sessions of Section C (chemistry) and the American Chemical Society resulted in a full program and a large attendance of chemists. The buildings of Tulane University were placed at the disposal of the Association, the meetings of Section C and the American Chemical Society being held in the chemical laboratory. The sessions of the American Chemical Society were presided over by President F. P. Venable of the University of North Carolina, while Dr. L. P. Kinnicutt of Worcester, Mass officiated in the sessions of Section C.

In his address as retiring president of the American Chemical Society President Venable presented an interesting historical account of the early days of chemical research in this country, the development of chemical societies and the publication of journals intended primarily for the stimulation of

research among American chemists. The address closed with an appeal for more earnest prosecution of research, especially by those connected with educational institutions.

"The Sanitary Value of a Water Analysis" was discussed by Prof. Kinnicutt the presiding officer of Section C. His wide experience in this important field gave added weight and interest to the conclusions he drew and to the standards he recommend.

It is difficult to make selections from the long list of papers presented. Some however were more general in their character than others and aid thus in such a selection.

The many sided claims of Agricultural Chemistry upon all branches of Chemistry were ably set forth in a paper by Dr. H. W. Wiley of the U. S. Bureau of Chemistry, while Dr. W. L. Dudley of Vanderbilt University discussed "Laboratory Designing and Construction," a subject in which all were interested and on which each chemist had his own views; but from the paper and the discussion which followed valuable ideas were gained for guidance in future laboratory construction.

Perhaps the most interesting paper, recording the results of careful research in the laboratory, was that on "Recent Experimental Researches on Osmosis" by Prot. Louis Kahlenberg of the University of Wisconsin. This work, to be published immediately, promises to be revolutionary. Prof. Kahlenberg found in ordinary rubber dam, such as used by dentists, a semi-permeable membrane which, unlike those used in former experiments on osmosis was permeable to colloids but impermeable to crystalloids. The accidental discovery of the great change in osmotic pressure on stirring the liquid lying next to the membrane throws great uncertainty on all results recorded hitherto on this subject.

Prof. W. D. Bancroft of Cornell University presented an interesting paper in which was offered a probable explanation of the marked difference in behavior of electrolytes in very dilute and in concentrated solutions.

A number of valuable papers were read by representatives of the U. S. Bureau of Sails. While far from complete it seems reasonable to hope that the work now being conducted by this Bureau will yet throw valuable light upon the whole subject of artificial fertilization of soils.

Hearty endorsement was given both by the American Chemical Society and by Section C to the efforts of the Committee of Manufacturers "in urging the passage of an act through Congress providing for the sale of tax-free alcohol under proper restriction." The inability at present to secure such tax-free alcohol is most largely responsible for the fact that many of our manufacturers of chemical products can not compete successfully with the manufacturers of "Germany, France and England where the laws permit the sale of tax-free alcohol for use in the arts and industries.

This short sketch will not permit of more detailed discussion of the program, but no account of a meeting of chemists would be complete without some word about the excursions which constitute such pleasant additions to the program, affording the members opportunity for inspecting chemical operations on a commercial scale and at the same time easy means for getting into closer personal touch with each other. The chief object of interest at New Orleans was the Sugar Experiment Station at which was exhibited every stage of the sugar industry from the cutting of the cane in the fields to the barrelling of the pure white sugar. The quaint character of the old French Quarter of New Orleans interested all.

THE CEMENT GOLD ORES OF DEADWOOD, BLACK HILLS, SOUTH DAKOTA.

BY JOSEPH HYDE PRATT.

The ore deposits of the Black Hills that are known as the "Cement Gold Ores" or "Fossil Placer" are to a certain extent peculiar to this general section of South Dakota and are in reality old auriferous placer deposits whose constituent sands and pebbles have become tightly cemented together with silica and iron oxide, forming such a hard, compact rock that now as they break the line of fracture is just as apt to pass through the pebbles of the conglomerate as the cementing material. The conglomerates of which the cement gold ores are a part are found over quite an extensive area as the basal portion of the Cambrian strata, but in most of the areas where they have been observed, they are but a few feet in thickness and carry little or no gold. There are two areas, one in the vicinity of Spearfish Canyon and the other in the vicinity of Lead, about 3 miles west of Deadwood, where the conglomerate reaches a thickness of from 20 to 40 feet. It is the latter locality, however, where the conglomerates are auriferous.

These conglomerates in the vicinity of Lead, Lawrence County, designated as the "Deadwood Cement Gold Ores" have been found over an area but a few miles in length and one mile in width which is exposed as isolated areas extending from just south of the city of Lead in a northerly direction across Bobtail Gulch, Sawpit Gulch, through the small town of Central and across Blacktail Gulch, making a total distance of something over 2 miles in this direction. They

are exposed on each side of this line at intervals so that the total width is about one mile. These conglomerates throughout this area vary considerably in thickness and, although they are all auriferous, they vary widely in the value of their gold contents and it is only in a comparatively small portion of this area that they are of economic importance. The most extensive mining has been done on the slopes of the mountains rising on both sides of Blacktail Gulch in what is known as the Whitewood Mining District. These cement gold ores rest unconformably on the old Algonkian schists and slates which are tilted at very steep angles and they have been derived from the destruction and the erosion of the auriferous quartz seams and veins that these schists contained. In the erosion of these schists there has been left a very uneven surface with ridges and shallow depressions that have been subsequently covered with gravels, which have produced the placer deposits. These are lying conformably with the sandstone and quartzite above. These latter rocks are capped by a flow of porphyritic rock in some cases a phonolite, which was the last rock formed and was intruded through the schists, conglomerate and quartzite as dikes, chimneys and laccolites.

The history of these rocks would read something as follows: The old Algonkian schists and slates which contained the auriferous seams and veins of quartz, were subjected to constant erosion during the early Silurian period, yielding sands, gravels, etc., which in time formed the conglomerate, sandstones, imposed thereon, which are a part of the Cambrian. During the formation of the Cambrian rocks the Algonkian rocks of this section were not submerged, although the Algonkian land was slowly subsiding. These gravels or conglomerates have been partially formed by the action of shallow seas, but they are also the result of erosion by streams and rivers, in the same manner as ordinary placer deposits that are now being worked by hydraulic methods were formed. In many cases the old water courses can be

distinctly traced, as they are exposed in mining the conglomerates. These Algonkian rocks were exposed as a rugged island with perhaps the highest point toward Harney Peak to the south, and in this direction the present cement beds have a tendency to become thinner. This whole Algonkian area was finally submerged and when it was raised again above the surface, the overlying rocks were not disturbed or tilted to any considerable extent. Later the schists, conglomerates and sandstones were cut by intrusions of quartz-porphry and phonolite, partly in the form of dikes and as laccolite or sheet flows, so that at the present time the rocks are capped by the eruptives. These intrusions have metamorphosed, somewhat, the conglomerates and sandstones, partially converting them into quartzite-conglomerate and quartzite. These intrusive flows also penetrated laterally into the rocks forming thin sheets, varying from a few inches to several feet in thickness.

While the different strata of sandstones and conglomerates are lying conformably with each other, the lower stratum of conglomerate is lying unconformably upon the Algonkian slates and schists.

While all of these cement ores carry gold values to some extent, they are found to be richer in some portions than in others. There are deep channels between rims of the schist which carry the greater amount of gold, and as the conglomerate is mined toward these rims it becomes thinner and thinner with diminishing values. These ancient channels were the natural lines of concentration.

These sedimentary and metamorphosed rocks have a general northerly course and are dipping in the same direction at a very flat angle (about 12 degrees), while the schists are dipping easterly at very steep angles. At the Homestake mine the small amount of cement or conglomerate ore that was encountered was near the summit of the hill in which are the immense open cuts of this mine. The conglomerate at the Homestake was thin, but becomes thicker toward Black-tail Gulch to the north and at the Phoenix and Jupiter mines

it is as much as 40 feet thick and 700 feet below the summit of the ridge. The thickness of these conglomerates rises from a few feet where they are just above some of the rims of the schists to about 40 feet, measured from the lowest point in the channel to Bessie Gulch. It is the few lower feet that are carrying most of the values, and that in direct contact with the schist, which would correspond in an ordinary placer deposit to the gravel resting on bed rock, contains most of the gold. It is therefore essential in mining these cement or conglomerate ores to clean up carefully all the fines and gravel resting on the schist and a few inches of the schist itself. Then again, the better values will be apt to be found in the troughs and depressions of the schist rock and have a tendency to become less and less toward the rims of the troughs or channels. Also any slight protuberance in the schist which may rise even but an inch or two above the general level, will have acted as ripples and thus have retarded the fall of the gold.

There has been some deposition of sulphides carrying gold in these conglomerates after their formation; but the larger portion of the gold is the free gold that was deposited in the original placer deposits.

It is essential in estimating the value of deposits of this character to determine to what distance from the enriched portions or channels and what thickness this material can be mined and milled as a profit. Thus to satisfactorily sample this ore, it must be so opened up that it can be done from and including a portion of the bed rock upwards for a distance of at least 5 feet as this thickness of material must be removed in ordinary mining.

Another possibility in connection with the mining of these cement ores is that of encountering workable deposits of the gold-bearing schist. The general strike of the band of auriferous schist, upon which is located the Homestake mine would indicate that it would pass about $\frac{1}{2}$ mile to the northwest of the main deposits of cement ores; but the strike of the

auriferous schists encountered in the Caledonia mine is N. 15° W. and its extension would pass almost directly under the conglomerate of Blacktail Gulch. In only a few instances have the underlying schists of these cement ore mines been tested, but in a number of cases where this has been done, fair values have been obtained. In testing the schists care must be taken to reach a sufficient depth before sampling so as to be beyond the influence of the gold that may have penetrated into the schist from the placer deposits.

It has been estimated that \$1,500,000 has been taken from these conglomerate or cement ores in the early mining; and in the aggregate there is still a larger value in these deposits.

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CHEMICAL RESEARCH IN AMERICA.*

FRANCIS P. VENABLE.

At the last meeting of the American Chemical Society, held in June at Buffalo, the secretary called for reports from various educational institutions as to the investigations then in progress in their laboratories. I was much struck by three things connected with these reports. The large number of institutions reporting, the wide field covered, analytical, inorganic, organic, physical, physiological, technical and the high grade of the work. These reports promise to be one of the most interesting features of future meetings, and the thought how meagre such details would have been a decade or so ago has led me to devote this presidential address to a discussion of the progress in chemical research in America.

It is to be expected that a people, thinly scattered over a vast area of new and unbroken country, confronted with the problems and difficulties of a nation just emerging from its birth throes, would have little time to give to the arts and sciences, and yet the impetus from the wonderful discoveries

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of Priestly, Scheele, and Cavendish and the splendid work of Lavoisier, with his revolutionary deductions, crossed the ocean and found its echoes in our wilderness. That Priestly, one of the greatest of these heroes of chemistry, should have been forced to flee from his native land and find refuge on these shores and should have continued his work here for a time brought the great movement nearer home to us. It is a pleasure to note the appreciation of his work shown by the offer of the chair of chemistry in the University of Pennsylvania, the first institution in this country to show an active interest in the development of chemical science, and the first one to have a distinct professor of chemistry in the person of the celebrated Dr. Benjamin Rush, whose appointment dated from 1769.

This interest took active shape in the formation of the earliest known chemical societies. The Chemical Society of Philadelphia was "instituted" in 1792, forty-nine years before the founding of the London Chemical Society, the first one to be established in Europe. Its first president was Dr. James Woodhouse, professor of chemistry in the University of Pennsylvania, and Priestly was one of the members. Probably the most important paper brought before it was one by Robert Hare on the "Discovery of Means by which a Greater Concentration of Heat Might Be Obtained for Chemical Purposes." In this he announced his invention of the oxy-hydrogen blowpipe—called by him the "hydrostatic blowpipe." Hare was then only twenty years of age. Later he became professor of chemistry in the medical school of the University of Pennsylvania and had a distinguished career as an author and chemist.

In 1811 there was founded by "a number of persons desirous of cultivating chemical science and promoting the state of philosophical inquiry" the Columbian Chemical Society of Philadelphia. The patron was Thomas Jefferson, the president was James Cutbush, professor of natural philosophy, chemistry, and mineralogy in St. John's College, and the membership seems to have been drawn from a wide area, as we

find among them Archibald Bruer, professor of mineralogy in Columbia College, New York; Thomas Cooper, afterwards professor of chemistry and president of South Carolina College; Edward Cutbush, professor of chemistry in Columbian University, Washington; de Butts, of the college of Maryland; Jackson, of Athens College, Ohio; MacLean, of Princeton; Silliman, of Yale; Troost, of Nashville, etc.; truly a national society and the first national society with a distinguished roll of foreign members.

The Delaware Chemical and Geological Society was organized in 1821. It was much more local in character and soon died for lack of support.

The papers presented before these societies are largely discussions of the discoveries or views of European chemists or are of a speculative character. Analyses are reported and methods of analysis devised, but synthetical research is lacking. Dr. Bolton, to whom I am indebted for the foregoing facts concerning the early American chemical societies (*J. Am. Chem. Soc.* xix. 716), suggests various reasons for the absence of research, but it seems to me that there is sufficient explanation in the necessity for devoting thought and strength to the development and building up of a new country and the small incentive to the search after truth for the truth's sake.

During the first quarter of the nineteenth century while European chemists were busied with atomic weight determinations, the testing of the law of multiple proportions, the extension of the list of elements and the multiplication of new compounds, the few American chemists who had access to laboratories were busied with the analysis of minerals and natural waters. It must be borne in mind that at this time there were no public laboratories either in this country or abroad to which students could readily find access. Universities did not provide laboratories for their students. Certain great teachers abroad, as Berzelius and Gay-Lussac had private laboratories but it was extremely difficult for a young worker to secure admission. The available equipment in this country

must have been meagre indeed. Even the illustration of chemical lectures by experiments was a rare thing. Liebig, in his autobiographic fragment, writes of the lectures which he heard in Paris in 1852. "The experiments were a real delight to me, for they spoke to me in a language which I understood and they united with the lectures in giving a definite connection to the mass of shapeless facts which lay mixed up in my head, without order and without arrangement." It was Liebig himself who a few years later at the University of Giessen opened to students the first public laboratory for research in chemistry.

In this country during the second and third quarters of the nineteenth century the *American Journal of Science* furnished an excellent medium for the publication of scientific papers. Established in 1816 by Benjamin Silliman at Yale University, it stood for fifty years almost alone for the upbuilding of scientific investigation in America and can boast ninety years of great usefulness. Without some such journal there is little encouragement for research. The scientific man finds a keen delight in the search of truth but he also loves to impart his discoveries to others and to win the commendation of those who can understand and appreciate his work and there must be some arena upon which controversies can be fought out and truth winnowed from the chaff. The chemical contributions to the *American Journal of Science* have dealt largely with the analysis of minerals, meteorites, and waters. This was especially true of the first few decades.

Schiff and Sentini (*Annalen* 228, 72) mention as the first work in pure chemistry in America the formation of a compound of arsenious acid with potassium iodide. This was described in the year 1830 by J. P. Emmett. He obtained the compound in the form of a white crystalline powder by adding potassium iodide to a very dilute solution of arsenious acid, or potassium arsenite exactly neutralized with acetic acid. Emmett was professor of chemistry in the University of Virginia from its foundations in 1825 to 1842, one of the band of brilliant men

brought over from England by Mr. Jefferson to aid in the up-building of his pet institution. With the exception of a few investigations by Robert Hare and the elder Silliman, which pertained rather to analytical, technical and mineralogical subjects, the communication of Emmett belongs to the earliest period of chemistry in North America.

It will scarcely repay us to linger over the years from 1830 to 1860. These were largely barren years. Not that chemical research was altogether lacking, but it was rather a dim and uncertain light beside the shining of such bright, particular stars as Dumas, Thénard, and Marignac in France, Graham in England, Stas in Belgium, and Wöhler, Liebig, and Kekulé in Germany.

One name stands out prominently during this period, conspicuous not merely because of the paucity of the work done by others but because of the sterling character of his own work. This is the name of J. Lawrence Smith. According to the elder Silliman the first piece of elaborate work or research in organic chemistry by an American was done by J. Lawrence Smith in 1842. Smith was a student of Emmett at the University of Virginia and a visit to Liebig's laboratory at Giessen formed the turning point in his life. His first organic research was entitled: "The Composition of Products of Distillation of Spermaceti." In this he first made known the composition of spermaceti and set aside the views of Chevreul.

Smith was later professor of chemistry in the University of Louisiana, then in the University of Virginia, and lastly in the University of Louisville where he furnished his private laboratory and did most of his work. He was an untiring worker and while much of his time was given to analyses of minerals and meteorites he was also a brilliant investigator. In analytical work we find him suggesting the use of potassium chromate for the separation of barium and strontium, and methods for the decomposition of silicates, especially the well known methods for the determination of alkalies. Only

once or twice did he touch again upon organic chemistry, the subject of his first research. He contributed some sixty or seventy papers up to 1870 and his total contributions number one hundred and forty-five.

Besides the work of Lawrence Smith during this period some excellent work was done by Mallet at the University of Alabama, where he was professor of chemistry and chemist to the Geological Survey of Alabama. Here he made the first of that long and brilliant line of investigations upon the atomic weights—the first atomic weight work done in America. Following up the master work of Berzelius upon the constants, Dumas, Marignac and many others in Europe were busily engaged in making new determinations of them with all the accuracy possible from their improved apparatus and new methods. In his scantily furnished laboratory, Mallet, a pupil of Wöhler, gave himself, so far as his many other duties permitted, to this exacting work, completing in 1856 his determination of the atomic weight of lithium from the chloride, and in 1859 the determination from the sulphate.

While not coming strictly under the head of researches it may be mentioned that some interesting speculations as to chemical theories were proposed by Cooke of Harvard and Lea of Philadelphia in the fifties and we have Hinrichs' remarkable deduction of the fundamental principle of the periodic system that the properties of the chemical elements are functions of their atomic weights, drawn from the consideration of their spectra. The synoptical table of Gibbs of Charleston falls just beyond this period, but is interesting to all Americans as so closely paralleling the practically contemporaneous work of Meyer and evidently independent of it.

In this diagram, prepared for his classes in 1872, he made use of the spiral very much as was done by de Chancourtois, Meyer, and Mendeléeff, anticipating in a measure the work of Spring, Reynolds, and Crookes. Further he anticipated some of the geometrical work of Haughton, observing that no linear equation can be constructed to give more than rude ap-

proximations of the atomic weights, and that to construct curves, two points of inflection, or contrary curvature, must be given. These are the serpentine cubics afterwards worked out by Haughton.

It is not a sufficient explanation of the barrenness of this period to say that laboratories and other facilities were poor. The absence of proper facilities had not proved a bar in the way of some of the greatest chemists of the century. The spirit of investigation was lacking in our colleges and few of the teachers had the necessary training for it. Very few indeed were those who had received an inspiration by coming in contact with the great masters of the science.

A few years after the close of the great civil war American students began flocking in large numbers to the German universities. A great many of them studied chemistry under the masters of the science such as Wöhler, Liebig, Fresenius, Kekulé, and Hoffman. The best laboratories and the most enthusiastic teachers were then to be found in Germany. The marvellous development of organic chemistry offered a most attractive field of research. Very little attention was given to this branch of chemistry in America before 1872 and the facilities for investigations in organic chemistry were very limited. Such work as was done was still chiefly in the line of mineral analyses or simpler investigation among the inorganic salts. The most important work was the determination of atomic weights and Americans may well be proud of their contribution to the knowledge of these constants, which can be worthily compared with those of any other nation. Cooke, Mallet, Clarke, Richards, Morley, Edgar F. Smith and others have been the leaders in this work, to which some of the best laboratories were largely given up during the last quarter of the nineteenth century.

The hundreds of young chemists, trained in the best methods of the Germans and inspired by their contact with vigorous original thinkers, returning home, brought with them an enthusiasm and an impetus which has since placed American

research well to the front. Those who had this training in the first half of the nineteenth century were comparatively few in number but they were practically the only ones who engaged in important investigations. Cooke, Mallet, Lawrence Smith, and Wolcott Gibbs all studied in German laboratories.

Aside from occasional scattered papers by a student here and there the first institution to send out annual reports of researches undertaken in its laboratory was the University of Virginia. These were regularly reported by Mallet in the *London Chemical News* beginning with the year 1862, and have continued for thirty-three years. In 1877 the Johns Hopkins University began its work and scientific research became an essential function of every true University. From that year we may date the building up of the graduate departments of our larger, wealthier institutions and the setting into motion that immense force which is giving America its proper place among the learned nations of the world—a force which has made Germany what it is to-day. Looking back over the work accomplished it seems scarcely possible that this truly great event took place only a little more than twenty-five years ago.

In 1879 this University gave to the growing body of American chemists the first suitable journal for the publication of their researches. It is true the *American Chemist*, published by the Chandlers in New York, had made its appearance in 1871, but it had failed to secure the adherence and support of more than a small body of chemists and had too technical a tendency for general support. It had already passed out of existence two years before the *American Chemical Journal* appeared. From the beginning the distinguished editor of the latter journal, our former president, Ira Remsen, President of Johns Hopkins University, and fully worthy of all honors which he has received, set a high standard and for twenty-six years has maintained its excellence.

It is difficult to overestimate the influence of such a journal

upon the development of research. At first the regular contributions came from a few laboratories only, notably the Johns Hopkins, Yale, Harvard, Pennsylvania, Virginia, and Cincinnati. Speedily the number grew until all parts of the country were represented and the valuable researches published placed the *Journal* on a plane with the best in the old world. It has thus done more to secure recognition for American research than any other one factor.

There was a crying need, however, for a strong well-organized chemical society. The memory of those early Philadelphia societies has faded out. The only common meeting ground for chemists was furnished by the sub-section of chemistry of the American Association for the Advancement of Science which did not rise, however, to the dignity of a section until 1881. It is true that this became one of the largest and most active sections of that association, gathering in annual meetings a hundred or more chemists. It is also true that certain local chemical societies were formed, but a national society was needed on the lines of the English or German or French Societies. The social need for such a society for receiving and entertaining distinguished guests was especially felt during the centennial year and so in 1876 the American Chemical Society was established in New York City. Though it failed to receive hearty support at first and the *Journal* appeared with discouraging irregularity and a woeful paucity of pages, it grew surely and the need for it was increasingly felt. When the happy idea of local sections was evolved many of the difficulties arising from the vast territory covered by the Society disappeared and a rapid growth ensued which has placed us in the fore-front of national societies. The *Journal* of the Society in 1889 contained 158 pages. In 1904 the total number of pages exceeded 2300, nearly 1700 of these being taken up with original articles. The number of members of the Society is rapidly nearing the 3000 mark.

Besides the *Journal of the Society* and the *American Chemical Journal* other specialized journals have arisen and worthily

represent American research. Among these may be mentioned the *Journal of Physical Chemistry*, the *Transactions of the Electro-Chemical Society*, the *Chemical Engineer* and others. The government scientific departments at Washington have contributed largely to the sum total of American research and a vast amount of investigation in agricultural chemistry has been done in the laboratories of the agricultural colleges and experiment stations established in every state.

Some years ago it was humiliating to see how the work of American chemists was almost completely ignored by foreign investigators and writers. It is a source of pride to-day that we are pressing forward in every branch of pure and applied chemistry and hold a worthy place among those who are adding to the world's store of knowledge and extending the bounds of science. A distinguished European authority has lately testified to the growing strength of American research and the way in which this country is forging to the front. But the fact remains that in these hundred years and more America has produced no great chemist, no Lavoisier to develop a new chemistry, no Wöhler to break down old barriers and add a new realm to the science, no Liebig to revolutionize the agriculture and industries of a world.

In conclusion let me plead for the encouragement of research among American chemists. I sometimes fear that the immense industrial development of the country will call away our strongest and most promising chemists to fields in which the material rewards are greater. And yet for the success of our chemical industries it is imperatively necessary that a large army of quiet workers should be busied in investigation, in the simple search after truth without a dream of the practical utilization of the results obtained. These are the men who patiently and laboriously forge the chain, link by link, that leads to some of the greatest economic changes, often changing the industries of a whole nation. It is chiefly in the laboratories of our colleges and universities that these investigators must be found. There alone can the necessary

freedom of purpose, of view and of action be preserved. There alone is the truth all-important and the money value unconsidered. No truth is insignificant, no fact is too trifling to warrant observation and careful accounting. It was in the laboratory of the University of Giessen that Liebig did his quiet work that made agriculture a science and made possible much of the comfort and luxury of the present day. It was Graebe and his discovery of synthetic alizarin in the laboratory of the University of Berlin which revealed the value of the almost useless coal tar and laid the foundations of Germany's great commercial growth. And many lesser cases might be cited. The governments of Europe vie with one another in fostering chemical research, Germany most wisely doing this in her universities. We as a nation cannot long afford to be behind them in this matter. In the close competition of the near future we must depend upon these toilers of the laboratories for our supremacy in the world's markets. But to my mind a far stronger plea for investigation lies in the inspiration which comes from such work, the broadening horizon and the fuller life.

What are the conditions necessary for chemical research and can we meet these conditions in most or all of our educational institutions? As the spirit of research seems to have developed with the increase in wealth of our larger institutions, many have come to regard research as a prerogative of these institutions and expensive equipment as a prerequisite to it. The idea is totally false and calculated to do much harm. It is accepted by many who hold positions in the smallest colleges as an excuse for their quietly sinking into a dull round of routine and unproductive drudgery. I do not believe that any teacher of science can keep fresh and enthusiastic and have a touch of inspiration about him unless he keeps in touch with nature through personal investigation of her facts and laws. And unless a teacher has these qualities he is not worth his salt and should not have the opportunity for dulling the originality of others. It too often happens that our

young chemists, having completed their researches at some of the larger institutions, published their dissertations, won their doctorates and secured professorships in minor colleges stifle their consciences with the excuse that they lack equipment or leisure, give up all idea of original work, settle down to a humdrum teaching of text-books and limit their ambition to drawing their meagre salaries and grumbling at their poor opportunities.

Let me tell you that which is no secret but is open to every one who has studied the history of the science, neither fine laboratory nor costly outfit nor abundant leisure are essentials for the search after nature's secrets. These are good and helpful things but the one essential is the earnest investigating mind, enthusiastic, determined, and plucky in surmounting obstacles. A quiet corner, a little apparatus, some spare time snatched from a multitude of other duties, these will suffice to give any one the opportunity to show what is in him. If he fails to avail himself of it, it is a tacit confession of his lack of energy, or originality, or pluck. He need not grumble at his meagre salary. He is getting more than he is worth.

I do not mean to be unjust or harsh but when I think of the thousands of young men who year after year are subjected to deadening, uninspiring, humdrum teaching of science and are thus lost to the ranks of our workers, and of the possible brilliant, elect spirits among that number, I must cry out at the terrible waste. The field of knowledge is vast and growing vaster with the ever widening horizon. The harvest is plentiful and the call for laborers is ever more insistent. It is necessary to impress this great truth that the true teacher must be a learner also, drawing constantly fresh inspiration from the fountain head.

THE CORAL *SIDERASTREA RADIAN* AND ITS POSTLARVAL DEVELOPMENT.*

H. V. WILSON.

The Coral Siderastrea Radians and its Postlarval Development. By J. E. Duerden. Washington, U. S. A. Published by the Carnegie Institution. December, 1904. Pp. 130, with 11 plates.

The handsome Carnegie memoir contains the record of an investigation begun at the Institute of Jamaica and subsequently carried on at the Johns Hopkins University and the American Museum of Natural History in New York. The author's prolonged residence in the West Indies gave him unusual opportunities in the way of command over living material, and the memoir makes valuable additions to our knowledge on many points of coral morphology.

An introduction deals with the systematic zoology and the habits of the species which is abundant and accessible in Kingston harbor. The form is obviously one of those convenient hardy types destined to play a part in laboratory investigations of histological and physiological character. Both the adult colony and the young polyp after metamorphosis grow in confinement and may be hand-fed. There follows an ample description of the anatomy of the adult. The species, like other West Indian corals, is possibly protogynous, although Professor Duerden calls to mind that Gardiner has established the converse phenomenon, protandry for *Flabellum*. Duerden takes up the question as to the way in which the coral skeleton, as a product of cellular activity, is

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produced. He confirms Miss Ogilvie's observation that the corallum can be seen in favorable parts of the adult and young polyps to be composed of minute skeletal units of a polygonal shape and exhibiting a fibro-crystalline structure. But whereas Miss Ogilvie interpreted these bodies as actual cells which were produced through the proliferation of the ectoderm, becoming calcified as fast as produced, Duerden regards them as secretory products which are laid down wholly external to the ectodermal cells. In support of this view, essentially that advanced by von Koch, Duerden finds that the layer of ectoderm concerned in the production of the skeleton is always a simple layer, and that, moreover, it is always separated from the corallum by a homogeneous mesogloea-like stratum. It is in this stratum of homogeneous matrix that the author believes the calcareous crystals forming the skeleton are first deposited.

A third section deals with the post-larval development. The larvæ, of the usual coral type, were obtained in July, and were kept under continuous observation for some months after attachment. Many valuable facts concerning the succession of the tentacles, mesenteries and various parts of the corallum are recorded in this section. A feature of interest lies in the attention paid to individual polyps. The partial transparency of the young animal permits of instructive views during life, and thus in one and the same individual the correlated development of the various organs could be followed from day to day. A result of this method was that periods of rapid growth and relative rest could be distinguished. The author points out that a phylogenetic significance possibly attaches to some of the more persistent stages, such as, for instance, that in which complete pairs of mesenteries (directives) are found at the two ends of the œsophagus, with two pairs, each consisting of a long (complete) mesentery and a short one, on each side of the œsophagus. This condition continued unchanged for a period varying from three weeks to three months. The author's theoretical views as to

the meaning of this particular stage are summed up as follows:

The long retention of freedom of the fifth and sixth pairs of protocnemes suggests to my mind an ancestry in which the mesenteries as a whole, including the metacnemes, were alternately long and short, excluding, of course, the axial directives. Among modern examples this is retained in the mesenterial system of the zoanthids, *Porites*, and *Madrepora*, and was perhaps characteristic of the Rugosa.

The building up of the corallum is followed out in detail through the formation of the third cycle of permanent septa. Among the illustrations of this part of the work special mention is due the microphotographs of macerated skeletons of developing polyps, and the figures of living polyps with the beginning skeleton *in situ*. Much interest attaches to Professor Duerden's account of the development of the septa. It has been hitherto assumed that the septa of a new cycle appear in the exocœles (*i. e.*, the space between two pairs of mesenteries), but are later embraced by the newly appearing pairs of mesenteries in such wise as to lie in the entocœles (*i. e.*, the space between the mesenteries of a pair). Thus the same septa would be first exocœlic and then entocœlic. In opposition to this scheme Duerden's observations lead him to the conclusion that while exosepta are formed in successive cycles, they never become entosepta. The cycles of entosepta are strictly new formations, appearing as do the primary six septa in entocœlic spaces. The succession of the cycles of exocœlic septa is maintained through the continued peripheral bifurcation of preexisting exocœlic septa. The bifurcated extremities become the (exocœlic) septa of a new cycle, while the main septum is incorporated in the growing body of one of the last formed cycle of entosepta. Having respect only to the actual facts as observed in *Siderastrea*, it has been found that any one of the permanent septa, later than the first six, has a double origin. It is in part a new formation (entocœlic), and in part a preexisting formation (exocœlic). The two parts fuse, and the fusion is interpreted by Professor

Duerden as the incorporation by a growing organ of the remnant of a vanishing organ. In a developing corallum according to this view exosepta are formed at each stage of growth, only to disappear as the permanent septa, entosepta, come into existence. Thus the development of coral septa affords an excellent example of substitution: temporary organs precede and are replaced by permanent organs performing the same function as the former. As a corollary to this conclusion the author expresses his belief that the exoseptal predecessors of the permanent septa do not wholly disappear in all corals, as independent structures, but persist in some species in the shape of the *pali* found in front of the larger septa.

THE SOURCE OF THE SUN'S HEAT.*

JOHN F. LANNEAU.

Doubtless the sun is now receiving more expert attention than any other single object in the material universe.

The world's telescopes daily confront it. At the Solar Observatory in Washington it is questioned almost hourly by Langley's exquisitely sensitive bolometer—sensitive to the one-millionth part of a centigrade degree. At Williams Bay, with the Yerkes' forty-inch telescope and Hale's marvelous spectroheliograph, its entire disk is photographed day by day, giving a permanent record of changes in the spots and faculae of the photosphere, and of the slow or rapid mutations in both the quiescent and the eruptive prominences of the chromosphere. And on Mt. Wilson near Los Angeles, California, is a veritable Sunbeam Laboratory—the unique Solar Observatory of the Carnegie Institute. It is a long, low, multiple-walled, canvas structure. At one end a great clock-controlled heliostat steadily reflects sunbeams horizontally to the far end mirror which returns them to its distant focus, forming there an exceptionally large, well defined image of the sun. This faithful image can be patiently scrutinized the day long, and its every detail permanently mapped by a five-foot spectroheliograph—the largest yet constructed.

ESTABLISHED FACTS.

Since Galileo's embryo telescope, three centuries of persistent effort have built a secure scaffolding for intelligent approach to the distant sun—a scaffolding of established facts.

*Address before the N. C. Academy of Science, May 18, 1906, by President John F. Lanneau.

1. The sun's parallax is now known to within two-hundredths of a second, its apparent diameter to within two seconds. These measurements show that its diameter is $109\frac{1}{2}$ times the earth's diameter; and that its distance from us is not quite ninety-three million miles.

2. Since the volumes of globes compare as the cubes of their diameters, the sun is more than a million times larger than this earth. In mass or weight, however, it is only 332,000 times greater. Its density, therefore, is only one-fourth of the earth's—or not quite one and a half times the density of water.

3. Gravity at the surface of a globe depends on its mass divided by the square of its radius. At the sun's surface therefore, gravity is nearly 28 times greater than gravity at the earth's surface.

That is, if a common brick here weighs 7 pounds, on the sun it would weigh 200 pounds. A brick there would weigh as much as a barrel of flour here!

LOOK AGAIN AT THESE FACTS.

The sun's size:—a vast globe more than three-fourths of a million miles in diameter. From its centre to its surface is nearly twice the distance from the earth to the moon!

The sun's mass:—its immense volume, as shown later, is a seething body of commingling gases—a great globe of glowing gas!

Expanding gas, growing larger and larger? Not at all. The expansive force lessens as the surface temperature is lowered by the cold of outer space; and it is checked also by the continuous inward pull of gravity. At a certain distance from the center, therefore, the outward and inward forces just counterbalance, giving definite size and boundary to the vast solar globe of gas.

"Light as gas?" Yes. But increase quantity, and weight increases. Double, treble, multiply quantity; and weight is

doubled, trebled, multiplied. The sun-globe of gas weighs as much as a third of a million worlds like ours!

The sun's distance:—ninety-three million miles. Our best modern rifled artillery will throw a ball a half mile in one second.

At that rate a cannon ball will go 30 miles a minute; in an hour, 1800 miles; in a day, over 40,000 miles; in a month, more than one and a quarter million miles. And keeping an undeviating course sun-ward with unslacked speed, the so swift cannon ball would not quite reach the sun in six years!

At that unthinkable remoteness, we yet feel here its panting July heat. There, yonder—beyond the swift missile's six year flight—at the sun, on its hot surface, how hot?

NATURE OF HEAT.

Facts in regard to the sun's heat have been reached slowly because of peculiar difficulties due to the nature of heat. It is not, as once held, the fourth form of elementary matter—earth, water, air, fire—nor yet, the subtile matter, "caloric", of a century ago.

Indeed, though intimately associated with all forms of matter, heat itself is not matter. It is force—energy—the force or energy of the constituent particles of either solids, liquids, or gases when the particles are in rapid motion—in minute, invisible, intense vibration.

Matter may be opaque or transparent. We perceive its heat by the sense of touch. Heat is recognized not visually, but palpably. It is felt.

As the feeling of warmth is the effect of the intense, invisible activity of the constituent particles of matter, so that of coldness results from their inactivity—their stillness.

Every hot body tends to coldness because its hedged-in multitudes of agitated particles, by the resistance of their recurring collisions, gradually settle towards rest.

Meanwhile, the molecular vibrations, imparted to the adjacent all prevading ether, are transmitted radially to distant

bodies, communicating vibratory motion to their particles. Thus a cold body may receive radiated heat from a distant hot body.

Air waves bring us the musical vibrations of a distant bell, and its pleasing sounds are reproduced in our aural nerves. Ether waves bring us the vibrations of a distant hot body, and its heat is reproduced in our tactile nerves.

Usually heat is produced in either of two ways, mechanically or chemically.

The heat of combustion in a wood or coal fire, or in a candle, is produced by the avidity of the oxygen particles of the air for the constituent particles of the fuel. Their clashings in chemical union maintain that atomic commotion which constitutes the heat of the fire or of the candle flame—heat produced chemically.

Hammer vigorously a cold anvil. Both anvil and hammer become hot. The checked energy of the descending hammer is reproduced in the invisible commotion of the iron's particles. Energy of mass is transformed into energy of molecules, into heat—heat produced mechanically.

Force, like matter, is indestructible. This is the gist of the broad physical law of the conservation of energy. If any force is seemingly annulled, Proteus-like it reappears in a new form—or, it is stored for future delivery.

The mechanical power of Niagara's water becomes in the shafts crowning dynamo electric power. And that electric power at Niagara becomes in distant Buffalo light energy, or heat energy, or again motive power.

From yonder far off, hot sun comes radiated heat; from this, our tropic and temperate heat, our wind and water power, and plant and animal energy; indeed, all terrestrial activity—from the modest up-peep of tiniest grass-blade, to the proud coursing high over continents and seas of the coming air-ship!

AMOUNT OF SUN'S HEAT.

The elder Herschel was the first to investigate the universe

of stars and nebulae. His illustrious son in 1838 took the first well directed step in the study of the sun's heat.

A sunbeam of a known section, imparting its heat to a definite weight of water, raising its temperature an observed number of degrees, in a certain length of time, gave the coveted, fundamental data.

Namely, the amount of heat received on a square foot of surface in one minute—taking as a unit of heat, the heat which raises a pound of water one degree Fahrenheit.

He found that the heat received at the earth from the sun in the zenith, is sufficient to melt an inch-thick layer of ice in 2 hours and 13 minutes.

That is, if an inch-thick shell of ice encompassed the sun, distant from its centre in all directions 93 million miles, that immense, remote ice shell would all be melted in 2 hours and 13 minutes.

With Young, our highest authority on solar facts, fancy such an inch-thick shell of ice kept intact and drawn inward toward the sun, all the while containing the same quantity of ice, becoming thicker as it lessens in size. When it touches the sun's surface, its thickness will exceed one mile.

That vast, solid glacier embracing the sun, at every point over one mile high, would all be melted by the the sun's heat in 2 hours and 13 minutes. It would melt a layer about 40 feet thick each minute!

All honor to Herschel's conception and achievement. His method was perfect, but not his instruments. Better means now prove that the sun radiates from its entire surface in one minute enough heat to melt encasing ice 64 feet thick!

TEMPERATURE OF THE SUN.

Within experimental limits Stephan's thermal law holds; namely, that the rate of heat radiation is as the fourth power of the absolute temperature. Assuming it to hold universally, this law and the known rate of sun's radiation—500,000 units of heat per minute from each square foot of solar sur-

face—give as the sun's surface temperature 12000° F.; about sixty times the temperature of boiling water!

With much more certainty a lower limit to the sun's surface temperature has been found experimentally.

Scheiner by ingenious use of the spectroscope, comparing lines of the solar spectrum with certain lines of magnesium, proved that the photosphere is hotter than the electric arc—that is, that its temperature is certainly above 7000° F.

So also, the heat at the focus of a powerful lens has furnished a lower limit in a very realistic way.

The sun's rays received on a lens or burning-glass are converged to its focus, producing at that point a high temperature. A point out in space to which the sun's rays naturally converge at an angle equal to the focusing angle of the lens, may be termed the space-point of equal temperature. Its distance from the sun is easily found. For the ratio of that distance to the focal length of the lens, is the known ratio of the sun's diameter to the lens' diameter.

At the focus of the largest lens yet constructed the high temperature produced instantly melted and vaporized the most refractory materials—platinum, fire-clay, carbon—everything tested.

And its space-point of equal temperature is about 250,000 miles from the sun's surface—a little further from the sun than the moon is from us.

If then our solid earth were placed at that distance from the sun—a quarter of a million miles—it would quickly melt—vaporize—vanish!

That certainly is the temperature at one-fourth of a million miles from the sun. Still higher is it at the sun's surface—and inconceivably higher, the internal temperature.

SOURCE OF THE HEAT.

How does the sun produce its enormous output of heat, and maintain its inconceivably high temperature?

Of four theories to be considered—if the newest suggestion can be called a theory—only one is perfectly satisfactory.

1. THE COOLING THEORY.

It is certain that the sun is not simply an intensely hot body slowly cooling. For in that case, its materially lowered temperature after thousands of years of human history would have caused decided climatic changes. But we know the vine, the olive and the palm are fruitful now just where they flourished in the days of classic writers.

2. THE COMBUSTION THEORY.

It is equally certain that the sun is not simply burning up—that its heat does not result from ordinary combustion.

As estimated by Young, its continuous great yield of heat could be produced by the consumption every hour of a layer of coal all over the sun's surface nineteen feet deep. That is, by burning one ton of coal hourly on each square foot of the sun's surface.

Lord Kelvin computes that were its vast mass solid coal environed by pure oxygen, and yielding its heat by combustion, it would be utterly consumed in five thousand years. It would, then, have dwindled more than one-third since Ptolemy's day. Yet, in the nearly two thousand years elapsed, it has certainly not diminished appreciably.

3. THE RADIUM THEORY.

Though not produced by combustion, the sun's heat is now surmised by some to be due largely if not entirely to radium—that most remarkable of known substances, discovered less than eight years ago by Mme. Curie.

Proofs of its properties are ably presented in Rutherford's "Radio-Activity". It is not only self-luminous, but is also self-heating, giving out every hour enough heat to melt more than its own weight—of ice—a fourth more.

It seems to be a very rare element. Tons of pitchblende yield only a few grains of radium.

But as radium evolves helium, and helium is known to be a chief component of the sun's chromosphere, it is suggested that the sun contains much radium.

Recall that the sun radiates from its entire surface in one minute enough heat to melt encasing ice 64 feet thick. With this measure of the sun's heat, and radium's heat emission per minute—melting one forty-eighth of its own weight of ice—as data, we readily find that the sun's heat equals the heat emitted by a mass of pure radium weighing nearly as much as the whole earth weighs. That much of this rare and peculiar element in the sun—our world's weight of radium—would yield its known output of heat.

The surmise that such a quantity of radium is there, rather segregates the sun from common matter.

Moreover, the properties of radium are none too well known.

At present, therefore, attributing the sun's heat to radium, is simply an interesting speculation.

4. THE MECHANICAL THEORY.

There remains for consideration the mechanical origin of solar heat—that is, the conversion of force, or the energy of moving matter, into heat energy.

There can be no doubt that many millions of meteoric bodies are hourly falling into the sun. We know that something like twenty million so-called shooting stars plunge into our atmosphere daily. Their checked energy of motion reappears in the air as light and heat.

But the heat thus imparted to our earth in a year has been shown to be less than we receive from the sun in one second!

Incomparably more of these meteoric bodies must plunge into the solar atmosphere contributing, however, comparatively little to the sun's heat. For while interplanetary space, at least as far out as the earth's orbit, is threaded by

countless meteoroids, if sufficiently numerous to produce by impact on the sun a large part of its heat, the outlying multitudes would affect perceptibly not only the periodic comets but also the planet Mercury. And no such effects have developed.

Helmholtz's theory of the mechanical origin of solar heat—his contraction theory announced in 1853—fully accounts for the sun's heat.

Recall that the inward pull of gravity at the sun's surface is nearly twenty-eight times gravity at the earth's surface. Abundant evidence furnished by the spectroscope, and the sun's known low density—not much greater than that of water—force the conclusion that the sun is a vast sphere of commingling gases, including the vapor of most, if not all, of the terrestrial elements.

As the sun contracts by its own powerful gravitation, the potential energy lost by gradual inward motion is replaced by equivalent heat energy. Every particle in the whole stupendous mass moving inward, contributes to the sun's inconceivable aggregate of heat. Helmholtz computed that an annual contraction of 200 feet in the sun's diameter is sufficient to produce the heat it radiates. More accurate recent measurements of the amount of heat radiated, indicate a greater contraction—a lessening of the sun's diameter by 300 feet annually.

This, even, is so slight a change in that diameter of near a million miles that in seven thousand years it will not appreciably alter the sun's apparent breadth. Our present most exact heliometers could not then detect the change—a change in the sun's angular breadth in seven thousand years of less than a single second!

But as the sun is a gaseous mass, its expanding force just counterbalanced by its gravitating force, it can contract only as its expanding force lessens by loss of heat radiated.

Will it not then cool as it contracts? Not necessarily. For Lane's law, discovered about 1870, asserts the paradox

that a globe of gas contracts by its own gravity and grows hotter, as necessary results of losing the heat radiated.

To illustrate: Let v = volume of a globe of gas; p = its surface gravity, or pressure; and t = its absolute temperature. When from loss of heat by radiation its radius contracts one-half, let v' , p' , t' represent respectively its changed volume, pressure, and temperature.

Since volumes compare as their radii cubed, and surfaces as the radii squared, v' will = $\frac{1}{8}v$; and the surface of v' will = $\frac{1}{4}$ the surface of v .

Since surface gravity increases as the square of the radius diminishes, the inward pull or pressure on the surface of v' will = 4 times what it was on the surface of v ; and as just shown, the surface of v' is only one-fourth that of v . Therefore, as a 4 times greater force will be exerted on a 4 times smaller surface, on a unit of surface the force or pressure on v' is 16 times the former pressure on v . That is, $p' = 16p$.

As is well known for a gas the product of its volume and pressure changes as its temperature changes.

$$\begin{array}{ll} \text{Hence,} & v \times p : v' \times p' :: t : t', \\ \text{or,} & v \times p : \frac{1}{8} v \times 16p :: t : t', \\ \text{or,} & 1 : 2 :: t : t', \\ \text{or,} & t' = 2t. \end{array}$$

Thus, when contracted to half its radius the globe of gas is twice as hot as at the outset. In general, as it radiates heat it contracts, and as it contracts it grows hotter.

If, then, our sun is truly gaseous from centre to surface, notwithstanding its vast output of heat it must, by contraction, continually grow hotter.

If, however, as is likely, the photosphere of incandescent clouds of carbon droplets and the central density have made it partly viscous, or partly liquid, or even semi-fluid, then the heat produced by contraction may just equal that lost by radiation.

In this case the sun's temperature will be constant—as probably it has been during the historic past.

With increased condensation, the heat of contraction will fail to replace that lost by radiation, and the sun's temperature will lower more and more until it becomes cold, solid, dark!

When by contraction its present diameter is reduced one-half, its density will be increased eight-fold. It may then be non-gaseous, and will doubtless be cooling. Contracting still, cooling more, radiating less and less heat, it must finally fail to support any of the present forms of terrestrial life—the world we know will be dead!

It is somewhat comforting to learn from Newcomb and from other eminent authorities, that this sad failure of our now glorious Day-Star, when its generous heat and light shall be quenched—our world's night of death—is probably distant in the future some ten million years!

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**PROCEEDINGS OF THE FIFTH ANNUAL MEETING
OF THE NORTH CAROLINA ACADEMY OF
SCIENCE HELD AT RALEIGH, N. C.,
MAY 18 & 19, 1906.**

FRIDAY, MAY 18TH, 1906.

This evening was devoted to a joint meeting of the Academy and Chemical Society in the Auditorium in the Agricultural Building at which the Presidential address upon the subject: "The Source of the Sun's Heat" was delivered by Prof. John F. Lanneau of Wake Forest College. The address was followed by a smoker.

SATURDAY, MAY 19TH, 1906.

A meeting of the Executive committee was held. The following members were present: President John F. Lanneau, Secretary F. L. Stevens, and Professor Collier Cobb.

The following members were nominated to the Academy by the Executive Committee: Mr. J. C. Temple, of the A. & M. College, Mr. F. C. Reimer, of the A. & M. College, Dr. E. W. Gudger, of Greensboro, Dr. Archibald Henderson, of Chapel Hill, and Mr. R. S. Woglum, of Raleigh.

Printed December 8, 1906.

A business meeting of the Academy of Science followed. The minutes of the last meeting were read and approved. The two following amendments previously submitted to the Executive Committee were received and adopted by the Academy:

1. To strike out of Article 2, Section 1, all of the second paragraph.

2. To strike out from Article 2, Section 2, the following words: "Three dollars and for associates."

The names of the following persons previously accepted by the Executive Committee were received and the candidates elected to membership in the Academy: J. C. Temple, F. C. Reimer, E. W. Gudger, Archibald Henderson, and R. S. Woglum. A nominating committee previously appointed reported the nominations as follows: For President, Professor Collier Cobb; Vice-president, Professor J. L. Lake; Secretary-Treasurer, F. L. Stevens; members of the Executive Committee in addition to the ex-officio officers, Dr. W. C. Coker, Franklin Sherman, and Professor J. F. Lanneau. The report of the Committee was adopted and members named declared elected to the respective offices.

The report of the treasurer showing the balance of \$141.43 was received. Mr. C. B. Williams was appointed as auditor.

Following the business meeting was held the meeting for the presentation of papers, a summary of which follows:

Autophytographs, ... Collier Cobb

Name suggested by C. H. White (Am. Jour. Sci., March, 1905) for a plant record formed by the extraction of coloring matter through decay of plant, or a black deposit reproducing perfectly the leaves of the plants, illustrated by specimens from the neighborhood of Wilkesboro, N. C., and elsewhere. Such records have also been made in geological past, and Professor Cobb reported fern autophytographs on carboniferous rocks from near Pottsville, Pa., exhibiting two different specimens of the same.

*Notes on the Variation in the Number of Eggs or Young
Produced by Some American Snakes . . . C. S. Brimley*

This paper gave the largest, smallest, and average number of eggs or young produced, according to the author's experience by the following species of American snakes: *Eutoenia sirtalis*, *Eutoenia saurita*, *Natrix sipedon*, *Haldea striatula*, *Storeria dekayi*, *Storeria occipitomaculate*, *Virginia valerie*, *Bascanium constrictor*, *Heterodon platyrhinus*, *Ophibolus getulus*, *Cyclophis aestivus*, *Coluber quadrivittatus*, *Carphophiops amoenus*, *Ancistrodon contortrix*, *Ancistrodon piscivorus*. Comments are also made on the confusion caused by the application locally of the same popular or local name to different species of snakes in different places, and by different names being applied to the same species.

The Embryo-sac of Liriodendron W. C. Coker

The development and structure of the embryo-sac of the ordinary tulip tree, *Liriodendron*, was explained with blackboard drawings. The special point of interest was that though this tree is ancient geologically, yet its embryo-sac presents no unusual features.

Sugaring for Moths C. S. Brimley

The author's experience in sugaring for moths in July, August, and September, was given. Names of the mixtures employed and how applied, and what species of moths and other insects were captured. Notes that a very large proportion of the attracted moths were species of economic importance, viz., the army-worm and cutworm moths, which do considerable injury to field and garden crops. Notes what insects were attracted to the sugared patches in the day time and also that rough barked trees were better to sugar than smooth-barked ones.

Rhoetic Flora of Moncure Shales Collier Cobb

Specimens of *Liriodendron* (?) reported from Deep River Trias in 1904 in association with *Macrotoenopteris*, and then regarded by speaker as Lower Trias, led to the tracing of this bed eight miles northeastward through Lockville to Moncure, and to the discovery of one nearly complete *Liriodendron* leaf and several fragments in association with lycopods, conifers, and equisetaceae with many examples of more modern plants yet to be determined, constituting what is probably a transition flora. Many of the specimens were from a well recently dug by the Seaboard Air Line Railway.

The Influence of Citrous Stocks on Scions Mr. F. C. Reimer

An investigation was made in Florida to determine whether the stock influences the scion in any way. The following outline covers most of the work which was done:

1. Influence on rate of growth—(a) in diameter, (b) in height.
2. On shape of tree.
3. On hardness.
4. On diseases.
5. On fruit—(a) amount, (b) quality, (c) season of ripening, (d) color, (e) dropping.

Interesting results were obtained which will appear in *Science* in full at a later date.

Mr. J. C. Temple discussed the bacterial flora of cow manure, showing the average number of germs present in fresh manure and in manure of different ages. The relation of these various germs to the nitrogenous material of the manure. He also presented important results concerning the distribution abundance and variation of the colon bacillus.

A paper by Lewis T. Winston in his absence was read by Dr. F. L. Stevens on "Bacterial Analysis of Various Lithia

Waters," in which it was stated that while most of the lithia waters were above reproach from a bacterial view point, some of them are of such condition that if submitted to the ordinary board of health analysis they would be condemned.

Liverwort Types for Elementary Classes . . . W. C. Coker

It was suggested that Pallavicinia, on account of its simple structure and easily demonstrated organs was far more suitable for elementary work than the more complex Marchantia which is generally used. Frullania Virginica was suggested as the best type for use in demonstrating the development of the capsule.

Mr. W. C. Etheridge explained a series of tests which he had made concerning the various methods of analysis of milk to determine the effect of the various media, various ages of plate, different degrees of acidity, and effect of ventilation upon the bacterial count.

Mr. C. S. Brimley presented a paper on the "Zoology of Lake Ellis, Craven County, N. C."

The Endosperm of the Pontederiaceae W. C. Coker

It was shown that the endosperm of the three genera of this family so far investigated was of two sorts. The definitive endosperm nucleus on its first division forms a wall separating the sac into an upper and a lower part. The endosperm in the upper part is quite different in appearance from that in the lower.

Food Adulteration Mr. W. M. Allen

This paper showed the great effect of the adulteration of human foods on mankind; how it affects both the health and the wealth.

It seems that the greatest danger to health lies in the use

of chemical preservatives in fresh meats and sausages by butchers and meat men, often ignorant, having no conception of what they are dispensing to their customers.

The meeting was well attended and interest was manifest.

Following the meeting for the presentation of papers the Academy of Science and the Chemical Section adjourned to Giersch's café where the visiting members were entertained at lunch by the Raleigh members of these two organizations.

F. L. STEVENS,

SEC. & TREAS.

THE BUILDING AND ORNAMENTAL STONES OF NORTH CAROLINA, A REVIEW.

BY JOSEPH HYDE PRATT, STATE GEOLOGIST.

There has recently been published by the North Carolina Geological and Economic Survey a report on the Building and Ornamental Stones of the State, which was prepared by Prof. Thomas L. Watson and Francis B. Laney, with the collaboration of Dr. George P. Merrill. This report represents nearly three years of field and laboratory work and shows that North Carolina is well supplied with a great variety of building stone materials, particularly those of a granitic type. With perhaps the possible exception of Georgia, it is better supplied with both as regards quality and variety than any of the other Appalachian States south of New England. When this fact is taken in connection with the mildness of the climate, which permits a long season of outdoor labor, and with the cheapness of labor itself, it will undoubtedly result in the development of a very extensive industry.

The granitic rocks have been especially studied by Dr. Watson, who worked almost exclusively in the granites and gneisses, with incidental reference to the associated eruptions, the diorites, diabases, and gabbros. In connection with the field work on these granitic rocks, he was ably assisted by Mr. Laney, who, however, devoted the larger part of his time to the marbles, limestones, sandstones, serpentines, and road materials,

Dr. Merrill's guiding hand is plainly seen in the character of the work and its form of presentation. There were but few tests made to ascertain resistance to crushing, shearing,

elasticity, or absorption, chiefly because the report does not pretend to be either exhaustive or final, but has been published to call attention to the deposits of stone, especially those of known economic importance, and to indicate how these can be opened and operated profitably. No chemical analyses were attempted, nor were they for the most part considered essential for the present work, as Dr. Merrill still adheres to his opinion that more can be learned from an examination in the field than through all known laboratory tests taken together. There are a number of chemical analyses given throughout the report which have been taken, however, from previous reports of the Survey.

The volume is divided into nine chapters, with a short appendix on stones for road building. In Chapter I, which is entitled Preliminary Generalities, the essential qualities of building stones are thoroughly discussed, attention being called to the influence that color has on the market value of a stone; the ease or difficulty with which a stone can be worked, and the location of the deposit with respect to transportation facilities. The surface features of the State are considered and it is shown that the geological formations which are capable of yielding desirable stone for structural purposes or ornamentation traverse the State in northeast and southwest directions. Beginning at the western margin of the coastal plain, there is found extending northeast from Raleigh a broad belt of gneissic rocks, succeeded on the west by one of brown sandstone, and this in order by belts of schist, granites, and gneisses to the State line, the last mentioned belt carrying in Cherokee, Graham, and Swain counties a narrow belt of marble. Within these areas there are numerous minor exceptions to the regular order mentioned above. The geographic position of the State is considered with reference to other than local markets and it is clearly shown that North Carolina is near the center of an area containing hundreds of large and prosperous cities and towns which will afford a market for a much larger amount

of building stones than it is now supplying, which should result in the development of the quarry industry on a much larger scale and without any danger whatever of ruinous competition.

Chapters II, IV, and VI take up in detail the building and decorative stones roughly classified as follows: (1) The crystalline siliceous rocks, including the granites, gneisses, and diabases, or traprocks; (2) the calcareous rocks, including all limestones and dolomites, both the crystalline and compact common varieties; and (3) the fragmental or clastic rocks, including the sandstone and clay slates. Those of the first group result either as erupted molten matter from the earth's interior or from the metamorphism of siliceous sediments. Those of the second group originate mainly as deposits of calcareous mud from the breaking up of shells, corals, and the remains of other marine animals on an old sea bottom. Those of the third group result from the breaking up of older rocks, and the accumulation on the bottom of lakes and seas of the resultant sand, clay, or mud in beds of varying thickness, to be subsequently hardened into stone.

"Now the essential difference between a marble and a compact common limestone, like those of Ohio or Kansas, is that the first has undergone, through the combined action of heat and pressure, just the right degree of change, or metamorphism as it is technically called, to develop in it crystallization and color; the essential difference between a brick or fire clay and a cleavable slate suitable for roofing, is, as explained elsewhere, that the first named still retains its plastic condition as it was laid down in the form of fine silt on a sea bottom, while the slate has by geological agencies, by actual movements of the earth's crust, been so squeezed and compressed as to lose all resemblance to its former self, and become the cleavable article of commerce we now find it.

"These processes of change, as noted above, are dependent very largely upon the actual movements; warpings and foldings as one might say, of the earth's crust and the heat and

chemical action which is thereby generated, and since these movements take place only with extreme slowness, whole geologic ages being occupied in their inception and completion, it follows as a matter of course that these metamorphic rocks, these gneisses, marbles and roofing slates, are found only among the older rocks and only in those portions of the country where this crust has been warped, compressed, and folded as in the process of mountain making."

Thus, one will find these rocks in their best development in those regions bordering along more or less extensive mountain ranges.

The area of the State containing rocks of the first class is very extensive and includes the three larger physiographic provinces of the State, namely, the coastal plain, the Piedmont plateau, and the Appalachian Mountain; but the greater part of the granites and other crystalline rocks of economic importance are included in the Piedmont plateau region. Along the inner margin of the coastal plain region there are a number of small workable areas of granite of excellent quality; but in the mountain region the large granitic areas are usually schistose in structure and are not very desirable for the higher grades of work in which granites are used. These crystalline rocks are discussed in groups:

I. The Coastal Plain Area, this area including Wilson, Edgecombe, Nash, Anson, and Richmond counties. In this region the areas capable of producing workable granite either lie close to or are crossed by the principal lines of railroad in the eastern part of North Carolina, rendering them easily accessible and providing ample facilities for transportation of the stone. The outcrops are usually large and are so located as to offer advantageous quarry sites. They are all biotite granites, showing a considerable range of variation in color and texture, from light gray to pink with occasionally a mixed yellowish and pink appearance. No systematic quarrying has as yet been undertaken and all that has been quarried has been used locally.

II. The Piedmont Plateau Region.

1. The Northeastern Carolina Granite Belt, including Wake, Franklin, Vance, Granville, and Warren counties. In this belt extensive workable areas of different grades of granite are found suited for all grades of work in which granite is used, except for the better grades of monumental work. Systematic quarrying, however, has been limited to areas in and around Raleigh, Wake county and at and near Greystone and Middleburgh, Vance county. These quarries have been operated quite extensively, furnishing stone to Eastern Virginia and Carolina, principally in the form of blocks and curbing for street purposes; and for general building purposes. Throughout this belt the granites show but little variation in mineral composition and, with one exception, they are biotite-granites. Minerals such as free sulphides and iron oxides, which are a source of discoloration to stone on exposure, are practically absent from the granites of this belt.

2. The Carolina Metamorphic Slate and Volcano Belt, including Orange, Durham, and Chatham counties. The country rocks of this belt comprise argillaceous, sericitic and chloritic metamorphosed slates and crystalline schists; sedimentary pre-Juratrias slates; and ancient volcanic rhyolites, quartz porphyries, and pyro-clastic breccias that are often sheared and altered andesites. Rocks of granitic composition have as yet only been noted in Orange county, and they are of doubtful commercial value except for railroad ballast and road purposes.

3. The Carolina Igneous Belt (The Main Granite Belt), including Mecklenburg, Gaston, Cabarrus, Iredell, Rowan, Davidson, Davie, Forsyth, Guilford, and Alamance counties. In this belt granite is one of the principal and most widespread rocks, and in each of the ten counties included in the belt, extensive areas of granite are exposed. Outcrops of firm and hard moderately fresh granite are not uncommon, and as a rule the exposures are large enough to admit of the

opening of large quarries without much stripping. The stone is usually well suited to the many purposes for which granite is used, and the belt is traversed in nearly all directions by lines of railroads which offer ample facilities for transportation. Notwithstanding these conditions, only a limited amount of quarrying has been done in these counties,



Figure 1. Boulder outcrop of orbicular-gabbro diorite, Hairston farm, Davie county, 10 miles west of Lexington, Davidson county.

with the exception of Rowan, where systematic quarrying has been developed on a large scale on the Dunns Mountain granite ridge.

There are two distinct phases of the granite developed, an even granular or normal and a porphyritic granite, both of which have wide distribution within the limits of the belt and, with one exception, represent different phases of the

same rock mass, the porphyritic texture grading into the even-granular. With hardly an exception the granites are mica (biotite) bearing and they vary in color from nearly white, through the lighter to the darker shades of gray. In several places over Dunns Mountain a beautiful shade of pink granite is quarried. This stone has attracted a great deal of attention and is much admired as a decorative stone.

4. The Western Piedmont Gneiss and Granite Belt, including Surry, Wilkes, Alleghany, Alexander, and Cleveland counties. In this belt the massive granites are less abundantly distributed than over other parts of the granitic areas. They are all biotite-bearing, usually of light color and of medium texture. No injurious minerals are, as a rule, observed. The rocks possess marked strength and durability and are very desirable granites for certain grades of work. Mt. Airy, Surry county, one of the principal localities in this belt yielding rock of this type, constitutes the largest quarrying center in the State. The demand for this stone is rapidly increasing and wherever used has given entire satisfaction both as regards color and durability.

III. The Appalachian Mountain Region, comprising McDowell, Buncombe, Henderson, Madison, Jackson, Haywood, Macon, Transylvania, Swain, Mitchell, Caldwell, Watauga, and Ashe counties.

No systematic quarrying has as yet been undertaken at any point in this mountain region, but numerous small openings have been made in exposures of the rock in many places, but the stone has been used entirely for local purposes. The larger amount of the rock quarried has been used for ballast and road purposes. Transportation is the serious difficulty confronting the quarrying of the mountain granite for building purposes, except for local use.

The report shows that North Carolina is well supplied with granite deposits that are easily accessible and are of a

quality that will permit of their being used for all grades of work.

Some of the rocks included under the head of the crystalline rocks are of especial interest and are mentioned more in detail.

Orbicular Gabbro-Diorite:— The orbicular gabbro-diorite is found on the Hairston plantation, Davie county, ten miles west of Lexington and one mile west of Oak Ferry. It occurs in high boulders occupying a low indistinct ridge, which culminates in a peak or knoll about thirty feet above the surrounding plain, Fig. 1. This is the only point where the orbicular rock outcrops prominently, but it can be traced in a southwest direction by means of residual decay for a distance of one-half to three-quarters of a mile in length and of several hundred yards in width. The orbicular rock undoubtedly occurs in the form of a typical dike penetrating the porphyritic granite and is parallel to and probably of the same age as some large, massive, unaltered diabase dikes in the vicinity which are intersecting the same rock..

This rock presents two distinct and strongly contrasted phases, one the pronounced orbicular and the other a granitic. Around the knoll referred to, the rock shows the typical orbicular texture, with the well rounded spheres varying in width from one-eighth to one inch and sometimes two inches in diameter. Some distance from the knoll the rock assumes a granitic texture, but is composed of the same minerals. Mineralogically, this rock is composed principally of a basic plagioclase feldspar, showing, as a rule, but slight polysynthetic twinning, uralitic hornblende, and diallage. Besides these, titanite, apatite, magnetite, and zircon occur as accessory minerals, and quartz, muscovite, calcite, and zoisite as secondary minerals.

In color the rock is dark, with a greenish tinge due to the dark green hornblende. It has a pronounced mottled appearance produced by the nearly black green nodules of hornblende in a ground-mass of the intensely white plagioclase feldspar.

The contrast is very pleasing and it is brought out much more prominently in the cut and polished surfaces. The spheres

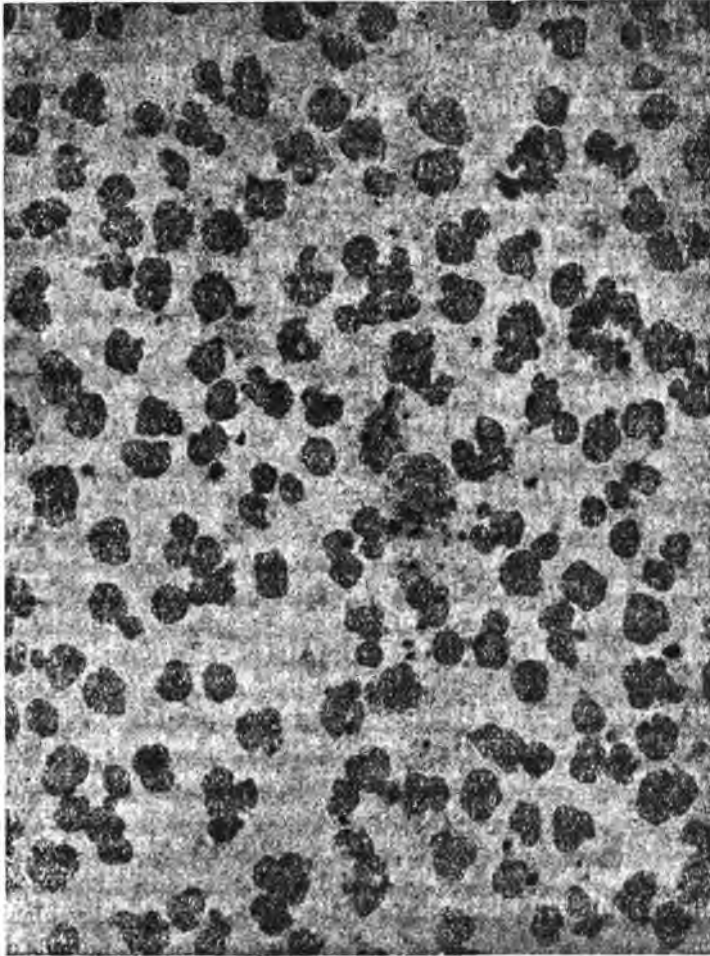


Figure 2. Photograph of fresh surface of leopardite showing the stone when broken at right angles to the long parallel streaks or pencils of a dead black color.

usually exhibit a fibrous, radiating structure from a common center outward. In some instances a small fragment of feldspar, quartz, or pyrite has been the nucleus about which the spheres of the hornblende have been formed. The concentric structure which is usually observed in orbicular rocks is not at all pronounced in the North Carolina rock; and where the spheres of orbicular granite and diorite heretofore described are composed usually of a number of minerals, the North Carolina rock is only composed of one, the dark green hornblende.

As a decorative or ornamental stone, this unique stone should find very great favor. It works easily and well as is shown by a polished column and sphere that are in the State Museum at Raleigh. That it wears well is demonstrated by the fact that some of this stone quarried prior to the Civil War and used for gate posts and steps to the house on the Peter Hairston property, do not show any signs of decay.

Quartz-Porphry (Leopardite):— Intersecting the biotite-granite at Belmont Springs $1\frac{1}{2}$ to $1\frac{3}{4}$ miles east of Charlotte, Mecklenburg county, is a dike of quartz porphry about one-half mile long, whose width nowhere exceeds 25 feet and which has been most appropriately named Leopardite. It is a dense, hard, tough and compact cryptocrystalline rock, which breaks with a conchoidal fracture. The fresh rock is nearly pure white, tinged in places a very faint greenish, and penetrated by long parallel streaks or pencils of a dead black color. If it is broken at right angles to these streaks, the surface is dotted with rounded irregular black spots varying from pin heads up to half an inch in diameter. This peculiar spotted appearance is well illustrated in Fig. 2. When the rock is broken or cut parallel with the direction of the pencils, the surface is streaked with long irregular black lines, which are sometimes approximately parallel and at others assume a dendritic or fern-like appearance, as illustrated in Fig. 3. These black streaks or pencils are not regularly distributed throughout the quartz-porphry, but in

some areas they are entirely absent, while in others they are crowded very closely together.

Mineralogically the rock is composed essentially of feldspar, both potash and plagioclase varieties, with a smaller amount of quartz,, which forms minute irregular interlocking grains. Considerable of it is intergrown with the feldspar in micrographic structure, forming more or less rounded disk-like areas. The black streaks or pencils are composed of oxides of manganese and iron and are supposed to represent the percolation of manganese and iron solutions through the rock.

The rock is susceptible of an excellent polish and could be used with splendid effect in inlaid work. On account, however, of its exceeding hardness and toughness and absence of any definite rift, it will be a rather expensive stone to quarry.

Unakite.:— In Madison county, about 5 miles southwest of Hot Springs, there is an irregular area of granite containing epidote as a characterizing mineral. The main mass of this rock is described as a dark pink and green epidote-biotite-granite of coarse texture and somewhat schistose structure varying from a typical schistose granite in which the quartz is present in the usual amount to a nearly quartzless rock of the same color and texture.

Penetrating this granite probably in the form of narrow veins is the unique and beautiful variety of granite known as unakite. This rock is composed of yellow-green epidote, dull pink or red feldspar and quartz. The unakite is not uniform in color and composition, but shows pronounced gradation into a highly feldspathic rock of pink color on the one hand and an epidote rock of a yellow-green color on the other. Usually in the veins the normal unakite, which is a coarse, massive rock of even texture, occupies the middle portion of the vein and graduates toward the enclosing gneiss either into the feldspathic or epidotic rock or both.

Under the microscope the unakite is shown to be composed of the usual granitic minerals such as orthoclase and

microcline in nearly equal proportions, a little plagioclase, quartz, occasional biotite, zircon, apatite, rutile, magnetite,

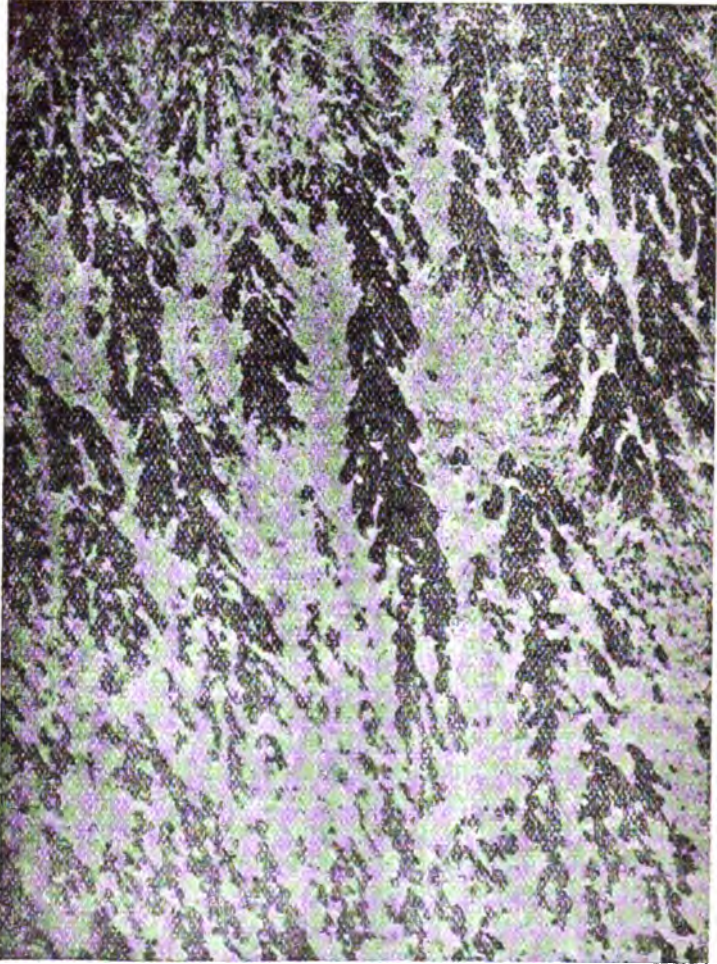


Figure 3. Photograph of a section of the leopardite cut parallel with the direction of the pencils.

and a few small grains of pyrite, with the secondary minerals epidote, chlorite, kaolin, and a green mica.

One of the best exposures of the unakite in its relation to the other granitic rock is along Roaring Fork and a short distance above its entrance into Meadow Fork. The commercial value of the rock would be for decorative or ornamental purposes, but at the present time it has not been developed sufficiently to determine what quantity of this rock can be obtained commercially.

In Chapter III there is a short description of the dikes and veins penetrating the crystalline rocks previously described which include, beginning with the most acid, true quartz veins, pegmatite, aplite and granite dikes of normal composition and texture; and abundant dikes of basic igneous rocks, of which diabase and diorite are the most common types.

Chapter IV treats of the calcareous rocks, limestones and marbles, taking up in detail their varieties, structure, weathering qualities, uses, and geographical distribution. The marble localities are confined to Cherokee, Swain, McDowell, and Mitchell counties. The only ones that have been developed commercially are those in Cherokee county. The marble of Mitchell county is perhaps worthy of more detailed notice on account of its occurrence and quality.

White Marble from Mitchell County:— This marble was first exposed in a railroad cut on the north bank of North Toe River near the mouth of Sink Hole Creek about $3\frac{1}{2}$ miles above Toe Cane Station. The marble is exposed in a bed about 60 feet thick interbedded with typical mica schists, and is exceptionally pure and of very uniform texture. As far as can be judged from the exposure of the blocks that are blasted out, it is remarkably free from joints. It has a beautiful pure white color and takes a good polish. It can be traced northeastward from the outcrop at the railroad for about a mile and is favorably located for quarrying, being on a mountain side about 100 feet above the valley, thus affording natural drainage and space for disposal of waste

material. Considering the location of this marble and its texture, purity, and color, it offers a very favorable commercial quarry proposition.

One peculiar feature of this marble deposit is the occurrence of a large pegmatitic vein in the midst of the marble as illustrated in Fig. 4.

The limestone areas are rather scarce throughout North Carolina and in no place are they of sufficient magnitude to be of any large commercial importance either for building purposes or for burning into lime. In a few localities a small

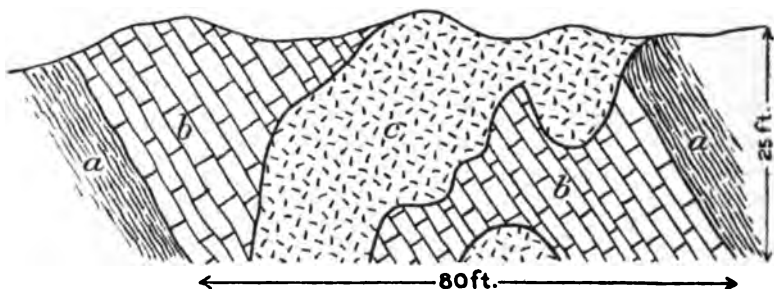


Figure 4. Pegmatic dike (c) cutting the Mitchell county marble (b). The country rock is a contorted typical mica schist (a) which at its contact with the marble is quite calcareous.

amount of the stone is used for road purposes or burned into lime for local use. In Buncombe county, about 2 miles north of Fletcher, two kilns having a capacity of 700 bushels per day have been erected for burning a limestone that is of a peculiarly fine grained structure, containing little or no impurities, the analyses giving 95.32 per cent. calcium carbonate.

The serpentines and verdantique marbles are described in Chapter V. They are at the present time of no commercial importance and they have been described in detail in a previous report of the North Carolina Geological Survey on Corundum and the Peridotites of Western North Carolina.

The sandstones and quartzites, which are taken up in

Chapter VI, are discussed more from a commercial than a scientific standpoint. Although in previous years there has been considerable quarrying of the sandstone from Moore county, in recent years the industry has come nearly to a standstill. This, however, has not been on account of the quality of the sandstone as much as transportation difficulties.

The dikes penetrating the sandstones are taken up in Chapter VII, which contains tables showing their distribution and their relation to the jointing of the sandstone.

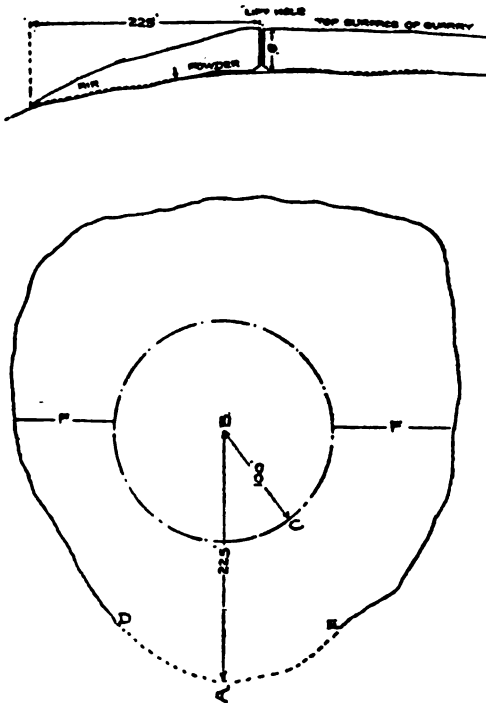


Figure 5. Diagram illustrating method of cleaving granite by means of compressed air. B, lift or drill hole; BO, area cleaved by powder; AFF, area cleaved by compressed air; DE, thin edge on down hill side of quarry where air escaped.

Chapters VIII and IX relate to the quarrying, working and weathering of building stones. One interesting method of quarrying building stones that is especially mentioned is that used by the North Carolina Granite Corporation at its Mt. Airy quarries, which is described as follows:

"In the center of the sheet or area to be lifted, a drill hole 2 to 3 inches in diameter is sunk 6 to 8 feet depth, depending on the greatest thickness of stone required, and the operation is continued by the discharging of successive small amounts of powder similarly as described under the method of quarrying by using water* until the crevice extends a distance of 75 feet or more from the hole in all directions. A pipe is then cemented into the hole and connected by means of a globe valve to an air pipe line from an air compressor. Compressed air at 70 to 80 pounds pressure is gradually admitted and the cleavage rapidly extends until it comes out upon the hillside in a thin edge as indicated by the cross-section, Fig 5. A sheet of several acres in extent may be raised in this manner, affording a bed plane approximately horizontal, to which the quarrymen can work, thus securing stone of any required thickness. The first time compressed air was used a pressure of 80 pounds was admitted into the cavity which had previously been extended to a distance of 100 feet from the

*After being drilled, the hole is fired by a succession of light blasts using in the first charge about a handful of blasting powder. The operation is begun by discharging about a quarter of a pound of dynamite in the bottom of the hole. This small charge of dynamite pulverizes the stone slightly at the bottom of the hole and forms a small chamber. The tamping is then cleaned out of the hole which is recharged in the same manner, this time, however, using about a handful of powder. The recharging of the hole is continued with small charges of powder until a small seam has been started at the bottom of the hole extending parallel with the surface. This is found out by using a small steel rod bent at the lower end and sharpened to a point and passing it up and down the hole until the crack is located. After the crack has once been started, the use of light charges of powder is continued, increasing the charges gradually as the seam is found to extend in all directions from the lift hole until the crevice extends a distance of 75 feet or more from the hole.

lift-hole. The power of the air, however, was too great for the easily splitting stone and the cleavage turned abruptly to the surface. In the next hole, however, the compressed air was admitted very gradually and the stone could soon be heard cracking in all directions and in about half an hour the cleavage came to the surface of the hillside as a thin edge some 225 feet from the lift-hole. To extend the cleavage by means of powder for a hundred feet would require from 6 to 12 days, and with water from 3 to 5 hours, while with the compressed air the larger area was split in half an hour.

Appended to the volume is a short description of stone found throughout the State that is suitable for road building, together with a table showing the results of tests made on certain stones suitable for use in road building.

Although this volume deals especially with the economic and commercial phases of the building stones of North Carolina, making it particularly interesting and valuable to contractors, builders, and dealers in building stones; yet there is sufficient detailed scientific work included to make it of considerable interest and value to the student of North Carolina geology.

WHERE THE WIND DOES THE WORK.*

BY COLLIER COBB.

No portion of the North American continent is so widely known, and at the same time so little known, as the chain of low-lying islands and fringing sand-reefs extending along the North Carolina coast for a distance of more than three hundred miles. This is especially true of Hatteras Island, a sand spit whose dangerous projection and shifting shoals have made this portion of our Atlantic seaboard a veritable graveyard of American shipping.

Distinguished scientists on both sides of the Atlantic have discussed the origin of Cape Hatteras without having set foot on the island or coasted along its shores. The origin of well nigh all the features of this coast have been discussed at long range, and yet hardly half a dozen people from the outside world have any personal acquaintance with the island.

It was on this coast that Fessenden and Thiessen experimented successfully with wireless telegraphy. At Kitty Hawk, on these banks, the Wrights conducted their experiments in mechanical flight.

Though difficult of access the inhabitants of these islands are in close touch with the rest of world by the telegraph and telephone lines of the U. S. Weather Bureau and the Life Saving Service as well as by the wireless telegraph.

Those who watch the reports of shipping need not to be told that winds are constant in this region. The strong winds of midwinter come from the north, and the gentler steady

*This article appeared in the *National Geographic Magazine* for June, 1906, with map and nine illustrations in half-tone from photographs, and is here reprinted with the permission of the editor of that magazine.

winds of midsummer and of the greater part of the year blow usually from a little west of south.

These constant winds were early taken advantage of by the inhabitants, and windmills for grinding corn dot the whole chain of islands, though most of them have now fallen into disuse. A small boy on Church's Island hauls freight for the people of his village on a car furnished with a sail and propelled by the wind.

The frequency of wrecks upon this coast is too well known to require comment; though such is the efficiency of the life savers, who brave the perils of any storm, that life is rarely lost here. But the lightship has sometimes been broken from its moorings on Diamond Shoals and driven upon the Hatteras Banks.

The strong north-winds pile the sands up into great barchanes or medianos, crescentic sand-dunes, known locally as whaleheads, which are steadily moving southward. These are best developed along the Currituck Banks, from Virginia as far south as the Kill Devil Hills, and numbers of them may be seen to the north and to the south of Currituck Light. These whaleheads are composed of singularly homogeneous blown-sands, the horns or cusps pointing to leeward, which is almost due south.

The prevailing winds from a little west of south have rippled the heterogeneous sands on Hatteras just south of the cape, on Shackleford at its southwest extremity, and on the southwest side of Smith's Island. These wind-ripples, started in sands exposed by the removal of a strip of forest next the shore, have grown in size to great sand waves and are advancing on forests, fields, and houses. As the sand-wave has advanced, it has taken up several feet of the loose soil over which it has passed, undermining houses, laying bare the roots of trees, and exposing the bones of the dead in the cemeteries.

Diurnal winds from the sea have piled the sands into small wandering dunes and hillocks, and even sometimes into sand

waves which are marching steadily inward and shoaling the waters of the sound. At Nag's Head, a large hotel constituting a solid obstruction, soon had a sand wave built up a short distance in its rear until the level of the roof was reached, when the wave moved forward and engulfed the hotel. In the immediate neighborhood two cottages suffered a similar fate. Here the land gained on the sound three hundred and fifty feet in ten years.

On the northern end of Hatteras Island a fishing village has been similarly buried, while the sand has entirely crossed the island at several places north of the cape. This movement of the sand was started just after the Civil War by the cutting of trees next the shore for ship timbers, and the section is still known as The Great Woods, though not a stick of timber stands upon it today. Pamlico Sound for two miles from the Hatteras shore is growing steadily shallower from the deposit of blown sand.

On Smith's Island a pilot's village has been buried beneath the sand wave for a number of years, but this has been quite recently resurrected and its houses are again occupied. On Currituck, below Caffey's Inlet Life Saving Station, the sand has advanced entirely across the land, and one man moving his home before the advancing sand has at last built his house on piles in the sound.

The writer has found by experiment that heterogeneous sands, consisting essentially of quartz, orthoclase, some mica, iron, bits of shells, and many mineral substances showing little if any decomposition,* ripple readily in the wind and are easily arrested. This he accomplished in one instance by planting the seed of a native pine and covering the dune with brush. In another case the movement was checked by the unassisted growth of grass upon dunes from which hogs and cattle were fenced out. Several native grasses on these islands are excellent sand-binders; but so far he has found no

*I consider these sands to be of glacial origin, scraped off the granite rocks of New England by the ice-sheet of the last glacial epoch.—O. O.

means of checking the movement of homogeneous sands that do not ripple, these consisting entirely of well rounded and wind-sorted quartz grains of the same size throughout a single dune.

Other trees beside the pine may be used as sand binders. Some live oaks and myrtles serve well in this capacity, and on Hatteras Island young olives and palms have been observed growing on the dunes, though this is the northern limit of both these trees, and they are even unknown on Ocracoke Island next to the south.

As already pointed out, the movement of these sands was in every case started by the deforesting of a strip of land next the shore; but in several instances nature has herself grown forests on dune sands. Above Kitty Hawk Bay large dunes are covered with a growth of pine, maple, oak, cedar, sassafras, locust, elm, beech, persimmon, sycamore, hickory, and in the damp interdune areas cypresses and gums. Here are many veteran pines, some of them having attained a diameter of three feet. An essentially similar forest is found growing upon the high dunes to the southwest of Cape Hatteras, but here we have to add the olive to the list, and there are broad interdune palmetto swamps.

On Bogue Banks, where deforesting has only just begun at two points, we have 20 miles of woodland, the virgin forest extending down to the water's edge and preventing the formation of dunes.

From Southport westward into South Carolina the dunes have moved northward and inland in some places completely filling the lagoons. At one point such a filled lagoon has produced a pine forest in something more than forty years.

The checking of these moving dunes presents a problem of increasing importance not only to the inhabitants of these sand keys, but to the navigators of the inland water-ways as well, and it is interesting to know that its solution is at hand, and that the encroachment of the sand may be effectually stopped.

It is fortunate that the strong north winds that pile up the sands and the strong east winds that cause the greater amount of the sand movement blow in the winter months rather than in the season of plant growth. The spring rains are usually of light intensity and long duration, and on Hatteras Island at least they come with the gentler southwest winds. Hence it is comparatively easy to plant grasses and shrubbery in late winter or early spring and have them gain a firm footing and accomplish something of their growth before the strong winds come.

In January, 1886, the writer planted the seed of the loblolly pine on the back of a dune and covered the area with brush cut from a near-by road in process of making. The brush served not only to break the wind but to conserve the moisture of the sands, and today there is a forest of several acres where twenty years ago was a moving sand waste. The method so common abroad of building a barrier dune by means of wind breaks has been tried several times along this coast, but always without success.

The atmospheric humidity of Hatteras Island is greater than that of any other station in the United States except in the Puget Sound region, and even there the excess over Hatteras is not great. Yet there are more days of sunshine on Hatteras than at Cape Henry, or Norfolk, or Wilmington. The heaviest rains come between late July and mid October, after the plants have done most of their growing for the year and when plants in many parts of the country are suffering greatly from the drouth.

The people of these islands are not the slothful bankers and rude wreckers pictured in song and story. They are fair women and brave men, most of whom live and do for others, —lifesavers, heroes. Their homes are comfortable and well kept; they attend regularly upon the services of the church, and their children are in school for eight months of the year, for the inhabitants of Dare County have voted upon themselves a special tax for this purpose. The islanders have

herds of small wild ponies, and flocks of sheep and goats, as well as cattle, on some of the islands.

True some primitive customs are preserved among them, and some early English forms of speech. Their lodges used in fishing and hunting are built after the most primitive types of straw thatch, while a higher type, similar to that used in the village of Gabii in the days of Romulus and Remus, is used as a temporary residence during their camp meetings in the summer, and this higher type of dwelling is on Hatteras built of palmetto thatch.

There is no better type of the average man than the native North Carolina banker.

The possibilities of these islands are as yet undreamed of by their inhabitants and utterly unknown to the outsider, who visits only the most barren of them in the duck-shooting season.

The regaining of the shore strip by reforesting the sands, and the retention of the dunes that are devastating the meadow lands, would make of Hatteras Island, at least, a subtropical garden, where southern fruits and early vegetables once plentiful here might come into the market. The game still lingering among the wooded dunes would be greatly multiplied, and the herds of wild ponies now dwindling away would again increase in numbers. Then conservative lumbering could be added to the industries of the island.

It is also within the range of possibilities that the black beachsands which are concentrated by wave action at a few points might be made to yield from their iron ores a return for the labor of gathering them.

THE CORAL *SIDERASTREA RADIAN*S AND ITS POST-LARVAL DEVELOPMENT.*

H. V. WILSON.

The Coral Siderastrea radians and its Post-larval Development. By J. E. DUERDEN†. Washington, U. S. A. Published by the Carnegie Institution. December, 1904. Pp. 130, with 11 plates.

This handsome Carnegie memoir contains the record of an investigation begun at the Institute of Jamaica and subsequently carried on at the Johns Hopkins University and the American Museum of Natural History in New York. The author's prolonged residence in the West Indies gave him unusual opportunities in the way of command over living material, and the memoir makes valuable additions to our knowledge on many points of coral morphology.

An introduction deals with the systematic zoology and the habits of the species which is abundant and accessible in Kingston harbor. The form is obviously one of those convenient, hardy types destined to play a part in laboratory investigations of histological and physiological character. Both the adult colony and the young polyp after metamorphosis grow in confinement and may be hand-fed. There follows an ample description of the anatomy of the adult. The species, like other West Indian corals, is possibly protogynous, although Professor Duerden calls to mind that Gardiner has established the converse phenomenon, protandry

*Reprinted from *Science*, N. S., Vol. XXIII., No. 587, Pages 497-498, March 30, 1906.

†Professor Duerden served as Acting Professor of Biology in this University during the year 1902-'03.

for *Flabellum*. Duerden takes up the question as to the way in which the coral skeleton, as a product of cellular activity, is produced. He confirms Miss Ogilvie's observation that the corallum can be seen in favorable parts of the adult and young polyps to be composed of minute skeletal units of a polygonal shape and exhibiting a fibro-crystalline structure. But whereas Miss Ogilvie interpreted these bodies as actual cells which were produced through the proliferation of the ectoderm, becoming calcified as fast as produced, Duerden regards them as secretory products which are laid down wholly external to the ectodermal cells. In support of this view, essentially that advanced by von Koch, Duerden finds that the layer of ectoderm concerned in the production of the skeleton is always a simple layer, and that, moreover, it is always separated from the corallum by a homogeneous mesogloea-like stratum. It is in this stratum of homogeneous matrix that the author believes the calcareous crystals forming the skeleton are first deposited.

A third section deals with the post-larval development. The larvæ, of the usual coral type, were obtained in July, and were kept under continuous observation for some months after attachment. Many valuable facts concerning the succession of the tentacles, mesenteries and various parts of the corallum are recorded in this section. A feature of interest lies in the attention paid to individual polyps. The partial transparency of the young animal permits of instructive views during life, and thus in one and the same individual the correlated development of the various organs could be followed from day to day. A result of this method was that periods of rapid growth and relative rest could be distinguished. The author points out that a phylogenetic significance possibly attaches to some of the more persistent stages, such as, for instance, that in which complete pairs of mesenteries (directives) are found at the two ends of the œsophagus, with two pairs, each consisting of a long (complete) mesentery and a short one, on each side of the œsophagus. This condition

continued unchanged for a period varying from three weeks to three months. The author's theoretical views as to the meaning of this particular stage are summed up as follows:

The long retention of freedom of the fifth and sixth pairs of protocnemes suggests to my mind an ancestry in which the mesenteries as a whole, including the metacnemes, were alternately long and short, excluding, of course, the axial directives. Among modern examples this is retained in the mesenterial system of the zoanthids, *Porites*, and *Madrepora*, and was perhaps characteristic of the Rugosa.

The building up of the corallum is followed out in detail throughout the formation of the third cycle of permanent septa. Among the illustrations of this part of the work special mention is due the microphotographs of macerated skeletons of developing polyps, and the figures of living polyps with the beginning skeleton *in situ*. Much interest attaches to Professor Duerden's account of the development of the septa. It has been hitherto assumed that the septa of a new cycle appear in the exocoel (i. e., the space between two pairs of mesenteries), but are later embraced by the newly appearing pairs of mesenteries in such wise as to lie in the entocoel (i. e., the space between the mesenteries of a pair). Thus the same septa would be first exocoelic and then entocoelic. In opposition to this scheme Duerden's observations lead him to the conclusion that while exosepta are formed in successive cycles, they never become entosepta. The cycles of entosepta are strictly new formations, appearing as do the primary six septa in entocoelic spaces. The succession of the cycles of exocoelic septa is maintained through the continued peripheral bifurcation of preexisting exocoelic septa. The bifurcated extremities become the (exocoelic) septa of a new cycle, while the main septa is incorporated in the growing body of one of the last formed cycle of entosepta. Having respect only to the actual facts as observed in *Siderastrea*, it has been found that any one of the permanent septa, later than the first six, has a double origin. It is in part a new formation (entocoelic), and in part a preexisting formation (exocoelic). The

two parts fuse, and the fusion is interpreted by Professor Duerden as the incorporation by a growing organ of the remnant of a vanishing organ. In a developing corallum according to this view exosepta are formed at each stage of growth, only to disappear as the permanent septa, entosepta, come into existence. Thus the development of coral septa affords an excellent example of substitution: temporary organs precede and are replaced by permanent organs performing the same function as the former. As a corollary to this conclusion the author expresses his belief that the exoseptal predecessors of the permanent septa do not wholly disappear in all corals, as independent structures, but persist in some species in the shape of the *pali* found in front of the larger septa.

CHLORAL— α —NAPHTHYLAMINE AND CHLORAL— β —NAPHTHYLAMINE.

ALVIN S. WHEELER AND V. C. DANIELS.

[Chemical Laboratory of the University of North Carolina.]

In an attempt to prepare condensation products of chloral with the two isomeric naphthylamines, we were able to obtain the addition products only. These latter were produced when the reaction was carried out at the ordinary, or better, somewhat reduced, temperature. If the reaction mass was heated to one hundred degrees in order to eliminate the elements of water and thus obtain a condensation product, the reaction went too far and black oily substances resulted. We studied the addition products, however, and found that they were formed by the addition of one molecule of chloral to one molecule of the naphthylamine. This work was done in the spring of 1905 and since the same compounds have recently been described [L. Rügheimer, Ber. d. deutsch Chem. Ges. 39, 1662] we wish to record our results, although we had intended to await further accumulation of material.

CHLORAL— α —NAPHTHYLAMINE, $\text{CCl}_3\text{CHOH.NHC}_{10}\text{H}_7$.

Seven grams of chloral (M. W.=147) were dissolved in 10 cubic centimeters of cold benzene and 5 grams of α —naphthylamine (M. W.=143), dissolved in 15 cubic centimeters of benzene, were added slowly with constant stirring. By surrounding the beaker with cold water the temperature is kept sufficiently low. About 50 cubic centimeters of ligroin are next added, causing a very dense white crystalline precipitate. The yield of the dried product was 7.8 grams, the theoretical being 10.1 grams. The melting point of the crude substance

was 89°C. Purification was effected by dissolving in as small an amount of cold benzene as possible and precipitating with ligroin. Vigorous stirring for about ten minutes is of considerable assistance in causing a complete precipitation. The melting point was raised to 92°C.

The following analytical results were obtained:

- I. 0.2265 gram substance was heated with 0.5908 g silver nitrate and fuming nitric acid in a sealed tube. 11 c.c. standard ammonium sulphocyanate solution (1 c.c.=0.0173 g AgNO_3) were used in titrating the excess of AgNO_3 .
- II. 0.2117 g substance gave 0.3900 g CO_2 .
- III. 0.2117 g substance gave 0.0727 g H_2O .
- IV. 0.3697 g substance gave 17 c.c. nitrogen at 22°C. and under a pressure of 756 mm.

	Calculated for	Found			
	$\text{C}_{12}\text{H}_{10}\text{ONCl}_3$	I.	II.	III.	IV.
Cl	36.61	36.88			
C	49.58		50.24		
H	3.48			3.81	
N	4.83				5.32

Chloral- α -Naphthylamine is soluble in glacial acetic acid, alcohol, and benzene and slightly soluble in ligroin and ether. It is a white crystalline compound, the needle like crystals collecting in bundles like sheaves of grain. It is insoluble in water and turns black when the water is heated. It can not be long exposed to light.

CHLORAL- β -NAPHTHYLAMINE, $\text{CCl}_3\text{CHOH.NH.C}_{10}\text{H}_7$,

Five grams of β -naphthylamine were dissolved in as little ether as possible and to this solution were added 7 grams of chloral in 10 c.c. of ether. After concentrating the solution to about 20 c.c., ligroin was added in considerable quantity. A dense white precipitate of the addition product was immediately thrown down. On account of the difficult solubility of β -naphthylamine in ether, too much of it was used in our first work and the isolation of the product after the addition

of ligroin was troublesome. Rügheimer uses chloroform in place of ether in this preparation. The yield of pure substance was rather small, about 27 per cent of the theoretical.

The following analytical results were obtained:

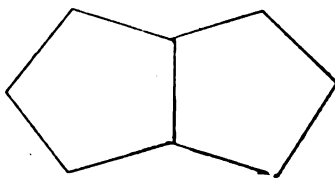
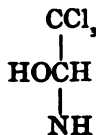
- I. 0.2289 g substance was heated with 0.6148 g silver nitrate. 1.53 c.c. of standard ammonium sulphocyanate solution (see above) were used to titrate the excess of silver nitrate.
- II. 0.2862 g substance gave 0.2332 g CO_2 .
- III. 0.2862 g substance gave 0.0961 g H_2O .
- IV. 0.2912 g substance gave 12.2 c.c. nitrogen at 18°C and under a pressure of 758 mm.

	Calculated for	Found			
	$\text{C}_{12}\text{H}_{10}\text{ONCl}_2$	I.	II.	II.	IV.
Cl	36.61	36.98			
C	49.58		50.08		
H	3.48			3.52	
N	4.83				4.82

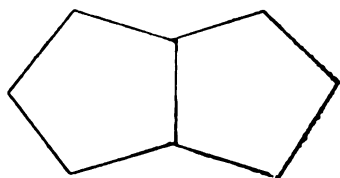
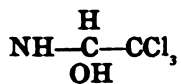
The β -isomer crystallizes in colorless needles and in the mass is light and bulky. It is soluble in ether, benzene, and alcohol but only slightly soluble in ligroin. It melts at 104°C and soon decomposes on exposure to the light.

The constitution of these addition products is represented by the following graphic formulae:

Chloral- α -naphthylamine,



Chloral— β —naphthylamine,



Chapel Hill, N. C.,
Sept. 24, 1906.

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ELISHA MITCHELL SCIENTIFIC SOCIETY

VOL. XXII

DECEMBER, 1906

NO. 4

PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY.

A business meeting was held on September 27, 1905, for the purpose of electing officers. The election resulted as follows:

H. V. Wilson, *President*.

Archibald Henderson, *Vice-President*.

F. P. Venable, *Corresponding Secretary*.

A. S. Wheeler, *Recording Secretary*.

Editorial Committee: W. C. Coker, Chairman, A. Henderson, J. E. Latta.

The following programs were carried out during the college year, 1905-1906:

161ST MEETING, OCTOBER 17, 1905

Paper Making—*A. S. Wheeler*.

On the Formation of Regenerative Bodies in Sponges When Kept in Confinement—*H. V. Wilson*.

162ND MEETING, JANUARY 23, 1906.

Tropical Notes—*W. C. Coker*.

A Group of Cross Ratios—*A. Henderson*.

Printed January 19, 1907.

163RD MEETING, FEBRUARY 13, 1906.

The Epiploical Appendages—*C. S. Mangum.*

The Cement Gold Ores of South Dakota—*J. H. Pratt.*

Colloidal Solutions—*R. O. E. Davis.*

164TH MEETING, MARCH 13, 1906.

President F. P. Venable addressed the society on "The Progress of Chemical Research in the United States."

165TH MEETING APRIL 10, 1906.

The Panama Canal—*William Cain.*

166TH MEETING MAY 8, 1906.

An Architectural Scheme for the University Buildings—*N. C. Curtis.*

Recent Work in Osmosis—*C. H. Herty.*

BUSINESS MEETING, SEPTEMBER 17, 1906.

The annual business meeting was held in Room 4, in the new Chemical Laboratory. The following officers were elected for the coming year:

C. H. Herty—*President.*

W. C. Coker—*Vice-President.*

F. P. Venable—*Corresponding Secretary.*

A. S. Wheeler—*Recording Secretary.*

Editorial Committee: W. C. Coker, Chairman, A. Henderson, J. E. Latta.

167TH MEETING, OCTOBER 9, 1906.

Geology and Forestry in the Ducktown Region—*Collier Cobb.*

Deforesting of the Ducktown Region by Sulphur Fumes—
Hampden Hill.

The Electric Smelting of Iron Ores—*C. H. Herty.*

168TH MEETING, NOVEMBER 20, 1906.

Denatured Alcohol—*A. S. Wheeler.*

The Mutual Absorption of Attraction by the Attracting
Particles—*J. E. Mills.*

A. S. WHEELER,
Recording Secretary.

MOLECULAR ATTRACTION. VI.

ON THE MUTUAL NEUTRALIZATION OF THE ATTRACTION BY THE ATTRACTED PARTICLES AND ON THE NATURE OF ATTRACTIVE FORCES.

BY J. E. MILLS.

Introduction. We have in several previous papers* discussed an equation of the form,

$$\frac{L - E_i}{\rho^2 d - \rho^2 D} = \text{Constant,} \quad (L \text{ is heat of vaporization of}$$

a liquid, E_i is the energy spent in overcoming external pressure, d and D are the densities of liquid and vapor respectively). This equation was derived theoretically on the assumption that the attraction between the molecules of a liquid varied inversely as the square of their distance apart and did not vary with the temperature. The equation has now been tested for thirty-three substances over wide ranges of temperature, (usually from near the freezing point of the liquid to the critical temperature), and the evidence in favor of the truth of the equation is exceedingly strong. This evidence will be briefly reviewed later. But admitting the truth of the equation, does it necessarily follow that the assumed law of attraction was the true one? Could it be possible that some other law of attraction operating either by itself, or in connection with other energy changes would give a similar equation? It is with this phase of the question that the present paper is concerned, and we will endeavor to show that the assumptions upon which the equa-

*Jour. Phys. Chem., 6, 209, (1902); 8, 883, (1904); 8, 593, (1904); 9, 402, (1905); 10, 1, (1906).

tion is based are correct, and that the equation is correctly deduced. Having given the evidence upon this point we show further that the conclusion may be drawn with considerable certainty that the molecular attraction is mutually absorbed by the attracted particles. Finally our knowledge of the laws of molecular attraction enables us to institute a comparison with other attractive forces and obtain some very suggestive results.

The conclusions to be drawn so closely concern our fundamental ideas of matter that we may be pardoned for briefly calling attention to laws and ideas, more or less generally admitted, upon which the present work is based.

THE FUNDAMENTAL IDEAS SERVING AS A BASIS FOR THE PRESENT WORK.

Our Idea of Matter. Since scientists are somewhat divided in their belief as to the ultimate nature of matter, we would, even though it involves repetition from a previous paper, make clear our own position in this regard, for the question with which we are dealing leads back to a consideration of the nature of mass as we measure it, if not to a consideration of the nature of matter. Because we use the term "molecule", "molecular attraction", and "distance between the molecules", we do not wish to be understood as possessing the idea that a molecule is *necessarily* a little hard sphere or some other particular shape of a piece of "something" extended in space. In the latter part of this paper we have something to say, (by way of speculation suggested by the facts to be considered), regarding the possible ultimate nature of mass. But in the present part of this paper we do not care to consider the nature of matter. We do not care whether it consists wholly of a "something" that possesses the property of extension, or wholly of energy, or is a mixture of the two. The law of gravitation has been shown to hold between certain large masses of a thing commonly called "matter". If later it happens to be proved that

matter, (in the sense of an "extended something"), is not reality and that only energy exists, we do not suppose the proof will greatly affect the calculations of the astronomers, or the position of the heavenly bodies, or their movement in accordance with the law of gravitation. The object of this series of papers is to throw light upon the law of attraction which exists between smaller masses of the same material of which these larger bodies are more conspicuous representatives. Following considerable precedent, we have called these "smaller masses" molecules, a term which conveys to every scientist a group of properties sufficiently clearly defined for the purpose in view. By the expression "distance between the molecules", we mean the distance between their centers of mass—an expression exactly analogous to the distance between two heavenly bodies. The "center of mass" is therefore a mathematical point, determined by the same principles that would be used for large masses. The term "molecular attraction" indicates a force which can be regarded as having its origin at the mathematical point thus determined. We are accordingly entirely free from any assumption as to the size of the particles (molecules), their nature, or the ultimate cause of the force. What we really assume is, that in nature certain forces *act as though they proceeded from mathematical points*, and we clothe these mathematical points with the name "molecule".

The Kinetic Theory of Gases. It is by no means necessary for us to point out how the laws of gases discovered by Boyle and Gay Lussac, and the simple relations connecting the densities of gases, discovered by Gay Lussac, but stated most clearly in the terms of Avogadro's hypothesis, that equal volumes of all gases contain the same number of molecules, are explained by the kinetic theory of gases. Nor how this theory similarly explains Dalton's law for the pressure of mixed gases and Henry's law governing the solution of a gas in a liquid. Nor how the theory lead Clark Maxwell to the discovery of the law governing the viscosity of

gases, and Waterston to the simple relation existing between the two specific heats of a gas. Van der Waals theory also is a fruit of the kinetic theory, and indeed the kinetic theory has been the stimulus and the guide to much of the work upon both liquids and gases. We do not believe that there are many chemists who will object to the acceptance of the kinetic theory of gases as a basis for further work.

According to the kinetic theory of gases we may regard the total energy of a gaseous molecule as being the sum of certain amounts of energy which may be quite clearly differentiated from each other. We would distinguish these energies as follows:

I. The chemical energy, or energy of combination of the atoms constituting the molecules. It can be shown, independently of theory, that the molecule must possess this energy at the absolute zero of temperature, -273°C . (We do not suppose that all motion ceases at this temperature. Just what part of the motion ceases is perhaps even yet a matter of doubt). To prove this proposition we will consider the reaction.

2.016 grams hydrogen (gas) + 16.00 grams oxygen (gas) = 18.016 grams water (liquid).

The amount of heat evolved by this reaction, when taking place at 18°C has been measured by Thomsen and found to be 68420 calories. Now the total amount of heat necessary to raise hydrogen and oxygen from the absolute zero to 18°C can be ascertained from the following data.

Hydrogen			Oxygen		
Melting point	14.1 ⁰		Below 50 ⁰		Travers
Boiling point	20.41		90.20		Travers
Specific heat of solid	2.3	Cals.	0.25	Cals.	Kopp
Specific heat of liquid	6.00	"	0.847	"	Alt
Specific heat of gas	8.410	"	0.2175	"	Regnault
Heat of Fusion	16.0		4.9	"	Estimated
Heat of Vaporization	125.0	"	50.92	"	Alt

The specific heat of ice is given as 0.4627 by Regnault and the heat of fusion of ice as 79.9 calories by Smith.

If to the energy added to the substance as specific heat of the solid, liquid, and gas, respectively, there be added the heat of fusion and the heat of vaporization, we will obtain the total heat required to raise the body from the absolute zero of temperature to the chosen temperature, in this case to 18°C. We have therefore for the total energy necessary to raise the temperature from 0° absolute to 18°C for,

2.016 grs. of hydrogen	= 2286 calories.
16.00 grs. of oxygen	= 2015 "
18.016 grs. of water	= 3865 "

The values given are probably maximum values and not very far from the truth except in the case of water, where we think the value would probably be considerably too large, due to the use of the specific heat for ice as found by Regnault between -78° and 0°C as representative of the average specific heat of ice, -273° to 0°. The value of the specific heat, judging from analogy, probably decreases as the temperature is decreased.

It appears therefore that in raising the 2.016 grams of hydrogen and the 16.00 grams of oxygen from the absolute zero to 18°C only 4301 calories of energy were required, while at this temperature 68420 calories were given out when they combined. Since the water formed possesses about 3865 calories of energy, it follows that the hydrogen and oxygen possessed at least 67984 calories of chemical energy at the absolute zero. Further, since only the difference between the chemical energy of the H_2 and O_2 on the one hand and of the H_2O on the other, is ascertained, we cannot make any statement as to the actual amount of chemical energy possessed by the H_2 and O_2 at the absolute zero. We can only say that it is certainly *not less than* 67984 calories. It may be many times more.

It follows from the above that the chemical energy has

been either entirely unaffected by the change in temperature of 291° , or has been affected only in a very minor degree. For a stable chemical body, where the change in temperature is not large, we have little hesitation in saying that the chemical energy, E_c , of the body is a constant.

1. $E_c = \text{constant}$.

We will return later to a further discussion of the chemical energy.

2. The Translational or Kinetic Energy of the Molecule. This energy for any particular molecule is equal to $\frac{1}{2}$ the mass of the molecule multiplied by the square of its velocity. It follows from the well known investigation of Clerk Maxwell that the velocities of the different molecules of a gas vary somewhat, but the variation is confined within rather narrow limits and only very few of the molecules have a velocity greatly above or greatly below the average molecular velocity. This theorem of Maxwell regarding the distribution of velocity among the molecules of a gas has been proved with strictness for the supposition that the molecules act on each other only at the moment of collision. For such a condition, using the constants adopted in former papers, the sum of the translational energy, E_k , of all of the molecules can be represented by,

$$2. E_k = \frac{1}{2} RT = 2.9817 \frac{T}{m} \text{—calories,}$$

where T is the absolute temperature, and m is the molecular weight referred to oxygen = 16.00 as standard.

It has never been shown that the translational energy of a molecule, when the molecule is subject to attractive force, can be calculated by this formula and the formula is therefore proven (with assumption of the kinetic theory) only for so-called "perfect" gases.

3. The Internal Energy of a Molecule. Experiments have shown that the specific heat of a gas at constant pressure is nearly a constant over considerable ranges of temperature. The

variation from absolute constancy appears to be due to variations from the gas laws, when the gases examined are far removed from the condition designated as "perfect" gases, and also to certain progressive changes taking place within the molecule as the temperature is raised—the progressive changes finally ending in the decomposition of the molecule. The measurements therefore make it very probable that for a perfect gas, and one that is chemically stable, (that is, one in which the chemical energy does not change with the temperature), the specific heat at constant pressure would be a constant.

But for such gases the law, $PV = RT$, holds true, and consequently, $PdV = RdT$, which for a change of one degree gives, $Pdv = R$. If σ_p and σ_v denote the specific heat at constant pressure and constant volume respectively, we have,

$$3. \sigma_p - \sigma_v = R.$$

If the increase in the translational energy of the molecules of any gas be subtracted from the specific heat at constant volume of the gas, a certain residue remains, (equal to zero for monatomic gases), which we shall consider as being due to a change in the internal energy, E_i , of a molecule. We will have, therefore,

$$4. \sigma_v = \frac{dE_k}{dT} + \frac{dE_i}{dT} = \text{Constant.}$$

True strictly only for a "perfect" gas.

Now from the theory by Waterson,

$$5. \gamma = \frac{\sigma_p}{\sigma_v} = \frac{dE_k + dE_i + R}{dE_k + dE_i}, \text{ } dT \text{ being equal to } 1^\circ\text{C.}$$

Wherefore substituting for R its value, $\frac{2}{3}E_k$, and solving,

$$6. E_i = \frac{\frac{5}{2} - \gamma}{\gamma - 1} E_k = 2.9817 \left[\frac{\frac{5}{2} - \gamma}{\gamma - 1} \right] \frac{T}{m} \text{ Calories.}$$

The internal energy in a perfect gas is therefore proportional to the translational energy.

The exact function of the internal energy required by a molecule has never been satisfactorily explained, but the fact that it is proportional to the translational energy leads to the belief that the internal energy is a direct consequence of the translational energy. It should be understood however, that equation 6 embodies no assumption whatever regarding the internal energy. That it is proportional to the translational energy follows necessarily, if the specific heat at constant volume is a constant and if the gas law, $PV = RT$, holds true. Nor will the possibility that this internal energy is merely the rate of change of, (the differential of), the chemical energy with the temperature, in any way affect our conclusion.

The data upon the specific heat of gases cannot be discussed briefly. Much of the data is given and discussed in Meyer's Kinetic Theory of Gases and in Nernst's Theoretische Chemie. Reference must be made to these or similar works for the actual data showing the constancy of the specific heat under the conditions set forth above.

4. The Energy of Position Due to the Attraction between the Molecules.

It is the purpose of this series of papers to show that this potential energy is due to an attractive force emanating from each molecule—that this force varies inversely as the square of the distance apart of the molecules—is mutually neutralized by the attracting particles—and is unaffected by temperature changes. We will later deduce the law governing this energy.

5. The Energy of Volume Due to the External Pressure. This energy, it is evident, is measured simply by the pressure times the volume. Denoting this energy by E_e we have,

7. $E_e = 0.041833PV$ calories,

Where P is expressed in millimeters of mercury. The constants used have been given in previous papers.

We can regard a perfect gas as a gas in which there is no

energy due to attraction and therefore the energy of such a gas could be represented thus:—

$$8 \quad \Sigma E = E_{\text{Chemical}} + E_{\text{Kinetic}} + E_{\text{Internal}} + E_{\text{External}}.$$

We can also regard a perfect gas as one in which the molecules are so far removed from each other that their mutual attraction has no appreciable effect in modifying the motions of the particles. Such a gas would still possess potential energy due to the attraction and we would therefore have,

$$9. \quad \Sigma E = E_{\text{Chemical}} + E_{\text{Kinetic}} + E_{\text{Internal}} + E_{\text{Attractive}} + E_{\text{External}}.$$

We could differentiate between the chemical energy as being a function of the atoms, the kinetic, internal, and attractive energies, as being a function of the molecule, and the external energy as being a function of the mass. The internal energy may be only the differential of the chemical energy with respect to the temperature, and consequently, be more directly a function of the atoms.

Equations 8 and 9 represent the condition of things in a perfect gas. If we now consider a saturated vapor or a liquid, where the molecules are so close together that the gas laws are not obeyed. it is evident from what has already been said that E_c is, if the body be chemically stable, the same as for that substance when existing as a perfect gas. The value for the external energy can be readily calculated, independently of assumptions, save the first law of thermodynamics. The internal energy, E_i , is, we have seen, proportional to the translational energy, E_k , and it is highly improbable that this proportionality would be destroyed by the nearness of the molecules and their increased mutual attraction. The kinetic energy of the molecules might itself be altered, equation 2 having been proved to hold only for a perfect gas. But where mathematical proof is lacking, experimental evidence has taken its place. Since Van't Hoff showed that for undissociated dissolved substances the osmotic pressure given by a dissolved substance was equal to

the pressure that the dissolved substance would exert were it a gas at that volume and temperature, it has been very probable that the osmotic pressure was due to the same cause as the gas pressure viz:—the motion of the dissolved particles, and therefore, the kinetic energy of the dissolved substance is the same that it would be for a gas under the same conditions of temperature and volume.

The molecules of the dissolved substance could not have an average kinetic energy different from the average kinetic energy of the molecules of the solvent, a fact long ago pointed out by Ostwald*. Therefore it seems probable that equation 2 holds also for liquids.

(The work of Morse and Frazert† shows that the theory of Van't Hoff needs some modification, and the work of Kahlenberg‡ is in evidence against the theory. We would, as regards the work of Kahlenberg, point out that his experiments numbers 53, 59 and 60 show that the dissolved substance was obeying Boyle's law for gases, (as concerns concentrations), and experiment 53 was *performed without stirring*. Also the manometer tube attached to Kahlenberg's osmotic cell, as given by him, was only of 0.5 mm. bore, and consequently, to produce a rise of 50 cms. in his manometer tube only $\frac{1}{10}$ of a cubic centimeter of liquid needed to enter the cell. The amount of *LiCl* leaving the cell was 0.0130 and 0.0267 and of cane sugar 0.1149 and 0.2205 grams and *the osmotic pressure is determined by the relative rate of inflow and outflow*. It seems to us possible, also, that thermometer effects of the cell were not wholly eliminated from influencing the results. We would not therefore, as yet, abandon Van't Hoff's theory and its results as a reason for believing that equation 2 holds also for liquids and that the average kinetic energy of the molecules of a liquid is equal to the

*Solutions, p. 147, 148.

†Amer. Chem. Jour. 34, 1, 1906,

‡Jour. Phys. Chem., 10, 8, 141, (1906).

average kinetic energy of the molecules of its vapor at the same temperature).

Further Traube finds that his "co-volume" for liquids varies as the absolute temperature*.

We give additional evidence bearing on the truth of equation 2 later in this paper.

If it be granted, then, that equation 2 holds also for liquids and for saturated vapors, the energy of a molecule of a vapor differs from the energy of a molecule of a liquid only because of changes in E_a and E_c . The latter change is easily calculated and we can therefore obtain a measure of the former—the energy change due to the attraction.

Expressing the above belief in a different form we may say that the energy necessary to change a liquid into a gas must, then, be spent solely in overcoming the external pressure and in altering the distance apart of the molecules. (Unless the molecule breaks apart also or nears the point of disruption). Denoting the heat of vaporization by L and the energy necessary to overcome the external pressure during the change from liquid to gas by E_c^* , $L - E_c^*$ must equal the energy spent in overcoming the molecular attraction.

DERIVATION OF THE EQUATION.

The derivation of the equation expressing the energy due to the molecular force as given in the first paper of this series was not carried out with strictness and we therefore give below a proof which we believe to be mathematically rigorous.

Let v and V represent the volume of the liquid and vapor before and after expansion, and d and D represent the corresponding densities. Let n equal the number of molecules and m the mass of each molecule. Suppose the molecules evenly distributed throughout the space occupied by them.

*Numerous papers. Among others: J. Traube, *Grundriss d. Phys. Chem.*, Boltzman, *Festschrift* (1904). *Sammlung Chemischer und Chemisch-technischer Vortraege* IV, 255.

Then

$$\sqrt[3]{\frac{v}{n}} \text{ and the } \sqrt[3]{\frac{V}{n}}$$

represent the relative distance apart of the molecules of liquid and vapor respectively.

It is highly improbable that the molecules of a liquid are evenly distributed throughout the space occupied by them. But if they are shifted from their ideal position by reason of the attractive force, the particles would gain in kinetic energy exactly so much as they would lose in potential energy. We may therefore, without error, consider them to be shifted back into this ideal position of even distribution, and the fundamental supposition upon which the mathematical work given below is based, is, that the molecules of a liquid and the molecules of its vapor have *per se*, (exclusive of E_a and E_e), the same energy *when they are in this ideal position of even distribution throughout the space occupied by them*.

If this supposition represents truly the condition of the molecular energy, then it is possible to find the law governing the forces which act between the molecules. For we have only to assume the law and deduce the corresponding equation. If the deduced equation fails to agree with the experimental facts then another law could be assumed and the process repeated until the correct supposition had been made.

We will assume that the molecular attraction varies inversely as the square of the distance apart of the molecules and is a mutual property of each pair of molecules. Hence the force

$$= \frac{\mu^2 m^2}{r^2}$$

where μ is the attraction at unit distance on unit mass, and r is the distance apart of the molecules whose mass is represented by m .

If now we consider two molecules whose distance apart is

$$X\sqrt[n]{\frac{v}{n}}$$

before expansion, (vaporization), after expansion their distance apart will be

$$X\sqrt[n]{\frac{V}{n}}$$

and the work done in pulling them apart will be,

$$10. \int_{X\sqrt[n]{\frac{V}{n}}}^{X\sqrt[n]{\frac{v}{n}}} m^2 \mu^2 \frac{dr}{r^2} = \frac{m^2 \mu^2}{X} \left[\frac{1}{\sqrt[n]{\frac{v}{n}}} - \frac{1}{\sqrt[n]{\frac{V}{n}}} \right],$$

where x is an unknown constant. If we in turn consider the work, W_i , done in pulling all of the molecules away from one molecule, and sum up, we will have, similarly,

$$11. W_i = m^2 \mu^2 \left[\frac{1}{\sqrt[n]{\frac{v}{n}}} - \frac{1}{\sqrt[n]{\frac{V}{n}}} \right] + \left[\frac{1}{X} + \frac{1}{X_i} + \frac{1}{X_s} + \dots + \frac{1}{X_{n-2}} \right]$$

If now we take any other molecule and similarly sum up the energy, W_s , required to pull all of the molecules away from it, we have for the work so done,

$$12. W_s = m^2 \mu^2 \left[\frac{1}{\sqrt[n]{\frac{v}{n}}} - \frac{1}{\sqrt[n]{\frac{V}{n}}} \right] \times \left[\frac{1}{X'} + \frac{1}{X'_i} + \frac{1}{X'_s} + \dots + \frac{1}{X'_{n-2}} \right]$$

By similarly extending the process to the other molecules, each considered in turn as a center, we will obtain a series of similar expressions, n in number. The last factor of each member of the series depends only upon the number of the molecules n , and is entirely independent of the nature of the

molecules or of the forces. We may, therefore, denote this last factor in the different series by $c_1, c_2, c_3, \dots, c_n$,

Summing up the entire n series of equations we will have,

$$13. \quad W_1 + W_2 + W_3 + \dots + W_n = m^2 \mu^2 \left(\frac{1}{r^{\frac{3}{2} \frac{v}{n}}} - \frac{1}{r^{\frac{3}{2} \frac{v}{n}}} \right) (c_1 + c_2 + c_3 + \dots + c_n),$$

The last factor of this equation is a constant if the number of molecules remains the same. Let C represent this constant. We have then for the total work of expansion, W ,

$$14. \quad W = m^2 \mu^2 \left(\frac{1}{r^{\frac{3}{2} \frac{v}{n}}} - \frac{1}{r^{\frac{3}{2} \frac{v}{n}}} \right) C,$$

Equation 14 gives the entire energy required to pull all of the molecules from each other as vaporization proceeds. It must therefore equal the internal heat of vaporization and we have for mass M ,

$$15. \quad M(L - E_e) = m^2 \mu^2 C \left(\frac{1}{r^{\frac{3}{2} \frac{v}{n}}} - \frac{1}{r^{\frac{3}{2} \frac{v}{n}}} \right).$$

Letting $d = \frac{nm}{v}$, $D = \frac{nm}{V}$, $M = nm$, we have,

$$16. \quad \frac{M(L - E_e)}{r^{\frac{3}{2} \frac{v}{d}} - r^{\frac{3}{2} \frac{v}{D}}} = \frac{M^2 \mu^2 C}{n^2 r^{\frac{3}{2} \frac{v}{m}}}$$

or for a constant mass,

$$17. \quad \frac{L - E_e}{r^{\frac{3}{2} \frac{v}{d}} - r^{\frac{3}{2} \frac{v}{D}}} = \text{Constant}.$$

The constant of equation 17 we shall call μ'

(In the previous derivation of this equation 17, we assumed, $c_1 = c_2 = c_3 = \dots = c_n$, a fact which is experimentally true, but which is contradictory to the law of attraction assumed, if the latter is unmodified. Also we regarded the

entire attraction in each case as proceeding from one molecule and being measured by

$$\frac{\mu m}{r^2}$$

instead of being a mutual property of the two molecules and being measured by

$$\frac{\mu^2 m^2}{r^2},$$

See further below).

EVIDENCE PROVING THE EQUATION.

The evidence proving that

$$\frac{L - E_c}{\sqrt{d} - \sqrt{D}}$$

is equal to a constant, has been given in the second, third and fifth papers of this series. We would only summarize here by saying that thirty-five substances have now been examined, at intervals of $10^\circ C$, over wide ranges of temperature, extending usually from near the boiling point of the substance to the critical temperature. Within ten degrees of the critical temperature there is an apparent divergence due to causes shown. Omitting these observations out of 435 remaining observations on 26 different substances only thirty differed from the mean value of the constant for that substance by more than two per cent and only four of these thirty by more than five per cent. The reason for most of these divergences is suspected and investigation will be made of them later. Of the remaining substances, CO_2 , N_2O , and SO_2 , gave probably as good agreement as the data permitted. Five other substances were associated and showed, as was to be expected, a divergence from a constant value for the constant, and $SuCl_4$ likewise showed a divergence. The evidence in favor of the truth of the equation is therefore

most convincing. That the equation itself is true can hardly be doubted when the evidence is examined. But does it follow that the assumed law of attraction is the true one?

THE NEUTRALIZATION OF THE ATTRACTION BY THE ATTRACTED PARTICLES.

The answer to this question is of great interest. For if the attraction between the molecules varies inversely as the square of their distance apart, then the resultant attraction caused by the large number of molecules must apparently increase as we proceed outward from an interior centrally chosen particle. This follows because the number of molecules increases as the cube of the distance from the centrally chosen molecule, whereas the attraction varies only inversely as the square of that distance. Hence the resultant attraction of any mass upon a particle exterior to the mass, when regarded as proceeding from the center of that mass, must vary as the mass.

The molecular sphere of action could not, therefore, be small but would embrace the entire mass taken. Now we regard the evidence that the molecular sphere of action is small, as being beyond dispute and will not attempt here to give the evidence for this idea. But we will point out that the derived equation 16, itself bears evidence that we have in previous papers been considering only one phase of the question. The equation was given in the form,

$$\frac{M(L - E_e)}{r^2 \bar{d} - r^2 \bar{D}} = \frac{M^2 \mu^2 C}{n^2 r^2 \bar{n}},$$

where M represents the mass of liquid taken for the vaporization. Now in the test of the equation, the number of molecules was assumed constant, and this was justifiable, since it would be experimentally possible to have them constant. But should they vary, we know experimentally that the left hand side of the equation varies simply with the mass taken,

While the right hand side of the equation varies, not alone because of the variation thus caused in M , but also because of the variation caused at the same time in C and in n . Since C is function of n , it might be supposed, as one occurs in the numerator and the other in the denominator, that the variation would cancel. We have not succeeded in summing up the $n(n-1)$ terms represented by the C of equation 16, but the relation of C to n can be obtained by attacking the problem somewhat differently,

Helmholtz in 1854 investigated the amount of energy that would be given out by the contraction of the sun in order to determine if the energy continually radiated from that body could be thus obtained. In this investigation he assumed that the particles of which the sun was composed were at the same temperature before as after the contraction, the excess of energy having been radiated off into space. He also assumed that the force acting between the particles of the sun's mass obeyed the Newtonian law of gravitation. Hence the investigation was essentially the same as the one above carried out. But Helmholtz made possible a better mathematical treatment by the assumption that the sun was homogeneous in density. We take the liberty of giving below the investigation as given by Helmholtz*.

"Consider a homogeneous gaseous sphere whose radius is R_0 and density σ . Let M_0 represent its mass. Let dm represent an element of mass taken anywhere in the interior or at the surface of the sphere. Let R be the distance of dm from the center of the sphere, and let M represent the mass of the sphere whose radius is R . The element of mass in polar coordinates is,

$$18. \quad dM = \sigma R^2 \cos \phi d\phi d\theta dR.$$

The element is subject to the attraction of the whole sphere within it. As can be shown, the attraction of the spherical shell outside of it balances in opposite directions so that

*Celestial Mechanics. Moulton, p. 58.

it need not be considered in discussing the forces acting upon dM . Every element in the infinitesimal shell whose radius is R is attracted towards the center by a force equal to that acting on dM : therefore the whole shell may be treated at once. Let dM_s represent the mass of the elementary shell whose radius is R . It is found by integrating 18 with respect to θ and ϕ . Thus,

$$19. \quad dM_s = \sigma R^2 dR \int_0^{2\pi} \left\{ \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \cos \phi d\phi \right\} d\theta = 4\pi\sigma R^2 dR.$$

The force to which dM_s is subjected is $-\frac{K^2 M dM_s}{R^2}$.

The element of work done in moving dM_s through the element of distance dR is

$$dW_s = -dM_s \frac{K^2 M}{R^2} dR.$$

The work done in moving the shell from the distance CR to R is the integral of this expression between the limits CR and R , or

$$W_s = -dM_s K^2 M \int_{CR}^R \frac{dR}{R^2} = \frac{dM_s K^2 M}{R} \left(\frac{C-1}{C} \right).$$

But $M = \frac{4}{3}\pi\sigma R^3$; hence substituting the value of dM_s from equation 19 and representing the work done on the elementary shell by $W_s = dW$, it follows that

$$dW = \frac{16}{3}\pi^2\sigma^2 K^2 \left(\frac{C-1}{C} \right) R^4 dR.$$

The integral of the expression from O to R_0 gives the total amount of work done in the contraction of the homogeneous sphere from radius CR_0 to R_0 . That is

$$20. W = \frac{4}{3}\pi^2\sigma^2 K^2 \left(\frac{C-1}{C} \right) \int_0^{R_0} R^2 dR = \frac{4}{15}\pi^2\sigma^2 K^2 \left(\frac{C-1}{C} \right) R_0^3$$

which may be written

$$21. W = \frac{4}{15} K^2 M^2 \left(\frac{1}{R_0} - \frac{1}{CR_0} \right)$$

Now if the contraction takes place between the limits

$$\sqrt[3]{\frac{3v}{4\pi}} \text{ and } \sqrt[3]{\frac{3V}{4\pi}}$$

we have for the work done,

$$22. W = \frac{4}{15} K^2 M^2 \left(\frac{1}{\sqrt[3]{\frac{3v}{4\pi}}} - \frac{1}{\sqrt[3]{\frac{3V}{4\pi}}} \right) = 0.9682 K^2 M^2 (\sqrt[3]{d} - \sqrt[3]{D})$$

Comparing this expression with equation 14 we have only to replace the attraction at unit distance between the elements of mass, by the molecular attraction at unit distance and observe that

$$C = 0.9682n^{\frac{2}{3}}$$

if the mass were of uniform density throughout. We cannot see how the transformation from a sphere of uniform density to one of uniformly distributed particles could effect any change in the energy relations involved. We would therefore write:

$$23. \frac{M(L - E_e)}{\sqrt[3]{d} - \sqrt[3]{D}} = 0.9682\mu^2 M^2$$

So long as a constant mass is taken the equation will reduce to the form,

$$\frac{L - E_e}{\sqrt[3]{d} - \sqrt[3]{D}} = \text{constant.}$$

If, however, the mass be varied, the equation informs us that the work done should vary as the five-thirds power of

the mass. It should require three and two-tenths times as much heat to vaporize two grams of a liquid as to vaporize one gram. As a matter of fact, we know that it only requires twice as much heat to vaporize two grams as to vaporize one gram. How is this discrepancy to be explained?

In attacking this problem we would call attention to the fact that the equation,

$$\frac{L - E_c}{\frac{1}{d} - \frac{1}{D}} = \text{constant.}$$

does correctly represent the variation of the energy change caused by the attraction with the distance, as is shown by the evidence accumulated in previous papers and as indicated in the brief summary above. It seems reasonable therefore to suspect the cause of the variation to be due to the numerator of the function representing the law of the force,

$$f = \frac{\mu^2 m^2}{d^2}$$

and not the denominator.

If now, we study the action of other attractive forces, such as magnetic forces, we find an explanation of the apparent contradiction at once suggested. The magnetic force varies directly as the product of the strengths of the poles and inversely as the square of their distance apart. But the interposition of a piece of sheet iron into the magnetic field between the magnet and the attracted particles serves to cut off the attraction, more or less completely, from the formerly attracted particles. Whether we look upon the interposed sheet of iron as actually absorbing the force, or as merely changing the direction of the lines of force, is not essential, the result at least is clear—particles beyond the interposed sheet are subject to less attraction because of the interposition. So if we were to imagine a magnetized particle of iron surrounded by other particles of iron, evenly distributed, and

similarly magnetized, the attraction would vary inversely as the square of the distance apart of the particles and yet the sphere of action of any particular particle would be small, due to the shielding action of the particles. And it seems to us that we may have here an exact representation of molecular attraction.

There is much indirect evidence to support such a conclusion. The attraction designated as chemical affinity is mutually absorbed by the combining bodies. At least the force is canceled by the combination so far as its effect on other particles is concerned. The combination of one sodium atom with one chlorine atom certainly serves to shield other bodies from the attractions of both the sodium and the chlorine, rendering them in a large measure chemically inert. And this action is commonly represented by saying that the "bond" of the sodium is neutralized or saturated by the "bond" of the chlorine. As we have just mentioned, a similar effect happens with magnetic forces. If electrical forces be considered we find again the same to be true. And if we undertake to consider yet more closely the nature of attractions in general, is it not apparent, that, whatever the ultimate nature of the attractive force may be, yet it cannot be infinitely multiplied? That just so much force must emanate from each particle, and if this force is exerted on one particle there will be somewhat less of the force remaining for the remaining particles. *Is it not unreasonable to suppose that a particle could exert its attractive pull upon one thousand, or one million, or one hundred million, particles and yet always have just as much of its force remaining to exert on other particles brought within the same distance?* We are not confusing force and energy. Can a man by means of a rope exert the same pull on each of twenty other men that he could exert on one man? Does not each stress exerted lessen by just so much the power of a man to exert a similar pull upon other things? Can we multiply, *ad infinitum*, any force about whose real nature we know anything at all, merely by the introduction

of further objects upon which the force can be exerted? Is there any form of wave motion, vibration or emanation, known, whose effect can be thus infinitely increased?

Look at the question from the other side. Is it reasonable, that the introduction of particles of matter into the space surrounding a molecule should be absolutely without influence on the emanation which proceeds from the molecule and gives rise to the phenomena of attraction? And that this filling in of the space surrounding a molecule with other particles of matter (or centers of energy, if you choose) should be able to continue, *ad infinitum*, without disturbing the attractive radiation proceeding from the body?

Moreover the mere fact that all of the attractive forces, whose law of variation with the distance we know; do vary inversely as the square of the distance from the attracting body, *is evidence, that the attractive force is in each case some sort of wave motion or emanation whose intensity decreases directly in proportion to the increase in the surface of the wave or emanation front*, since and because this surface varies as the square of its distance from the origin. Can we, on the one hand, believe that the intensity of these forces thus decreases, and on the other, consider them unmodified by the presence of matter and capable of infinite multiplication by the introduction of additional matter into an infinite range of action?

In place of such a conception we would introduce the idea *that the attractive forces, whatever their nature, whether chemical, molecular, magnetic, electrical, or gravitational, which proceed from a particle, are definite in amount. If this attraction is exerted upon another particle the amount of the attraction remaining to be exerted upon other particles is diminished by an exactly equivalent amount.*

We are of course aware that no such diminution of the attraction is supposed, or is supposed possible, for gravitational forces. That certain facts have led to the belief, difficult of conception as it may be, that this force attracts every particle of matter in the universe exactly as if no other

particle of matter were present. And that these facts would at once be urged as contradicting the above statement as to the attractive forces. We would answer by calling attention in detail to the evidence in favor of the above idea.

FURTHER EVIDENCE REGARDING THE MOLECULAR ATTRACTION

As regards the molecular attraction the conclusions cited above have been based on evidence which, for purposes of examination, may conveniently be divided into five steps as follows:—

1. The equality of the energy *per se* of the molecules of a liquid and of the molecules of its vapor at the same temperature. That is $E_c + E_k + E_i$ for a molecule of a liquid equals $E_c + E_k + E_i$ for a molecule of its vapor, the difference in their energy consisting of a difference in E_a and E_e .
2. The assumption that the attraction was a mutual property of each pair of molecules, varying directly as the mass of the molecules, (so long as the same chemical body is considered), and inversely as the square of the distance apart of the molecules. Later modified by 5 below.
3. The derivation of an equation expressing the energy relations necessitated by the above two conditions.
4. The experimental evidence deduced in favor of the equation.
5. The facts leading to the supposition that the molecular attraction is mutually absorbed by the attracting particles.

Examining these steps separately, let us see which are open to doubt. Considering first the fourth—the experimental evidence in favor of the equation—we would here add nothing new. But we would put one portion of the evidence in a more striking form. We will use the equation derived by Helmholtz in 1854 as expressing the energy given out by

the contraction of the sun, to calculate the energy given out by the contraction of isopentane from a gas to a liquid. The equation of Helmholtz has been given, equation 22, and is, for a change of volume corresponding to a change of density from D to d ,

$$22. \quad W = 0.9682K^2 M_{58}(\rho^2 \bar{d} - \rho^2 \bar{D})$$

To apply the equation to one gram of isopentane we have only to substitute for the constant in the above equation, the value for this constant that we have already found, 105.4. The equation then becomes,

$$24. \quad W = 105.4(\rho^2 \bar{d} - \rho^2 \bar{D}).$$

We give below in Table 1 the data and the results. The values given by equation 24 are in the column headed W . Under the heading $L - E_e$ we give the values of the internal heat of vaporization as actually determined from Young's measurements. It is inconceivable to us that the agreement between W and $L - E_e$ could be accidental.

TABLE 1

Temperature	Density of liquid	Density of vapor	$\rho^2 \bar{d} - \rho^2 \bar{D}$	U	$L - E_e$
0° C.	.6382	.001090	.7585	79.9	81.8
20	.6196	.002358	.7194	75.8	75.2
40	.5988	.004480	.6781	71.5	70.7
60	.5769	.007819	.6340	66.8	66.4
80	.5540	.01284	.5871	61.9	61.8
100	.5278	.02022	.5357	56.4	56.7
120	.4991	.03106	.4788	50.5	50.9
140	.4642	.04728	.4127	43.5	44.0
160	.4206	.07289	.3316	34.9	35.4
180	.3498	.1258	.2085	21.4	21.0
185	.3142	.1574	.1899	14.7	14.0
187	.2857	.1838	.0905	9.5	8.9
187.4	.2761	.1951	.0712	7.5	6.9
187.8	.2843	.2343	0.0	0.0	0.0

The formula used by Helmholtz to represent the contraction of the sun does represent the contraction of isopentane from the gaseous to the liquid condition. And not only isopentane but essentially as well all of the non-associated substances ex-

amined by us. *For we have already published* similar comparisons for all of these substances*, the only difference being that we added to the energy given out by the contraction, the value of the energy due to the action of the external pressure, and thus obtained the heat of vaporization. We have here republished the results for isopentane as coming from Helmholtz' formula only to emphasize the statement that we have not gone beyond the facts when we declare that, *as regards variation with the distance, the law of molecular attraction is identically the same as the law of gravitation, and precisely the same formula is applicable to both.*

The formula is,

$$25. E_a = \mu'(\sqrt[3]{d} - \sqrt[3]{D}).$$

where μ' has the meaning assigned previously in this and earlier papers.

As regards the third step mentioned above—the derivation of the equation—we can detect no flaw in the proof given by the author, or the proof given by Helmholtz, the basis of the mathematics as expressed in steps 1 and 2 being granted.

As regards the second step—the assumption of the law of the attraction—the fact that a true equation was deduced, entirely theoretically, from the assumption, is the surest evidence that the assumed law was the true one. One point remains to be examined here. Could any other law of attraction have produced the same equation, or one equally in accord with the facts?

To satisfy ourselves upon this point we have in a similar manner deduced the corresponding equations on the assumption that the attraction varied as the third, the fourth, the fifth, and the sixth, powers of the distance between the molecules. These equations would take the form:—

For the inverse third power of the distance,

*See third paper of this series, Tables 1 to 21, and fifth paper, Tables 15 to 24.

$$26. \frac{M(L - E_c)}{d^{2/3} - D^{2/3}} = 0.4841\mu^2 M^{1/3} = \text{Constant for a constant}$$

mass.

For the inverse fourth power of the distance,

$$27. \frac{M(L - E_c)}{d - D} = 0.3227\mu^2 M = \text{Constant for a constant}$$

mass.

For the inverse fifth power of the distance,

$$28. \frac{M(L - E_c)}{d^{4/5} - D^{4/5}} = 0.2420\mu^2 M^{5/3} = \text{Constant for a constant}$$

mass.

For the inverse sixth power of the distance,

$$29. \frac{M(L - E_c)}{d^{5/3} - D^{5/3}} = 0.1936\mu^2 M^{2/3} = \text{Constant for a constant}$$

mass.

Applying these equations to isopentane, the constant given

by equation 26 is shown in the column headed $\frac{1}{r^3}$ the constant

given by equation 27 in the column headed $\frac{1}{r^4}$ etc. The val-

ues at the critical temperature, 187.8°C, were obtained by substituting for $L - E_c$ its value,

$$.0,31833 \left(V - v \right) \left(T \frac{dP}{dT} - P \right),$$

and getting the limit of the resulting equation where V was equal to v . The resulting equations are,

For the limit of equation 26,

$$30. \text{Constant} = .0,477 V^{1/3} \left(\frac{dP}{dT} T - P \right)$$

For the limit of equation 27,

$$31. \text{ Constant} = .0,31833 V^{\frac{1}{2}} \left(\frac{dP}{dT} T - P \right),$$

For the limit of equation 28,

$$32. \text{ Constant} = .0,239 V^{\frac{1}{2}} \left(\frac{dP}{dT} T - P \right),$$

For the limit of equation 29,

$$33. \text{ Constant} = .0,191 V^{\frac{1}{2}} \left(\frac{dP}{dT} T - P \right),$$

The critical temperature is 187.8°C, the critical pressure is 25020 millimeters of mercury, the critical volume is 4.268, and

the $\frac{dP}{dT}$ at the critical temperature is 406, from the measure-

ments by Dr. Sydney Young.

It will be seen that when the equation is deduced on the assumption that the attraction varies inversely as the square of the distance apart of the molecules *a constant is obtained, and on no other supposition does the corresponding equation give a constant.* It is evident therefore that *no simple change in the assumption as to the variation of the attraction with the distance will serve to explain the fact that the heat of vaporization does vary proportionately to the mass taken.*

TABLE 2—ISOPENTANE.

Tempera- ture	$L-E_c$	d	D	$\frac{1}{r^2}$	$\frac{1}{r^3}$	$\frac{1}{r^4}$	$\frac{1}{r^5}$	$\frac{1}{r^6}$
0°C.	81.35	.6892	.001090	107.2	111.2	127.5	147.8	171.5
50	68.63	.5881	.005967	104.5	103.6	117.9	139.6	166.8
100	56.67	.5278	.02022	105.8	97.9	111.6	134.6	165.1
150	40.13	.4445	.05834	106.9	92.9	104.0	126.7	160.5
180	21.04	.3498	.1268	103.4	85.7	98.9	114.7	148.1
187.8	0.0	.2344	.2344	107.2	86.9	94.0	114.4	148.3

The law of the attraction assumed, seems, therefore, to be the only assumption that will give an equation in accord with the facts.

As regards now the first step—the equality of the energy *per se* of a molecule of a liquid and of a molecule of its vapor—we have already stated in outline the facts which led us to that belief. This first step is the most fundamental and important step in our work and is perhaps the most open to doubt. The fact that using this belief as a basis we derived an equation that appears to be true, is, perhaps, again the best evidence that the belief, expresses, at least partly, the truth. But only in part, for in attempting to derive a direct method for testing this belief we find that it will require some modification. An account of this work could not be introduced within the limits of this paper and we hope shortly to publish this investigation in a separate article. Recognizing the doubt, we would state that any errors introduced by our statement have undoubtedly canceled, since one is certainly able to calculate the energy given out by the contraction of vapor into a liquid from the same formula used to calculate the energy given out by the contraction of the sun.

As regards now the fifth step—the conclusion that the molecular attraction is mutually absorbed or canceled by the attracting particles—we have only to say here that the conclusion is necessitated by the four previous steps and the further well known facts, that the molecular sphere of action is small, and that the heat of vaporization of a liquid is proportional to the mass of the liquid taken for evaporation.

THE NATURE OF THE ATTRACTIVE FORCES.

We would now return to a consideration of the idea proposed on page 119 of this paper, *that the attractive forces, whatever their nature, whether chemical, molecular, magnetic electrical, or gravitational, which proceed from a particle are definite in amount. If this attraction is exerted upon another particle the amount of the attraction remaining to be exerted*

upon other particles is diminished by an exactly equivalent amount.

We shall call attention to what is actually known as to the action of attractive forces by the following table.

Force	Medium of propagation	Effect of temperature	Is the attraction neutralized?	Is the attraction directive?	Law of distance	Numerator factor of force.	
Chemical	Ether	No effect	Neutralized	Yes	?	Nature of atom	Nature of atom
Molecular	Ether	No effect	Neutralized	?	$\frac{1}{d^2}$	Nature of molecule	Nature of molecule
Magnetic	Ether	?	Neutralized	Yes	$\frac{1}{d^2}$	Strength of pole	Strength of pole
Electrical	Ether	?	Neutralized	Yes	$\frac{1}{d^2}$	Charge	Charge
Gravitational	Ether	No effect	Not neutralized	No	$\frac{1}{d^2}$	Mass	Mass

The general resemblance between these forces is so striking, we think, as to warrant a very serious consideration of any idea which leads to the belief that all of the forces do not follow the same law. Are they not perhaps all, in fact, one and the same force?

Considering the chemical force of attraction, the fact that this force does vary as some function of the distances apart of the atoms concerned has, we think, been already shown by the work of Richards* and Traube†. The latter says, "*Wie von mir zuerst festgestellt wurde, ist der Raum eines Atoms keine Konstante, sondern ändert sich von Stoff zu Stoff und ist um so kleiner, je grosser die Affinität des betreffenden Atomes zu den Atomen ist, mit welchen es in unmittelbarer Verbindung steht. Die Kontraktion der Atome ist daher ein unmittelbares Mass der Affinität.*" Concerning Traube's claim to priority in this discovery see remark by Richards‡. While we prefer not to accept the conclusion of these investigators that the

*Proc. Amer. Acad. of Arts and Sciences, XXXVII, 1; XXXVII, 15; XXXVIII, 7; XXXIX, 28.

†Zeitschrift für Anorganische Chemie, 40, 380 (1904).

‡Proc. Amer. Acad. of Arts and Sciences, XXXIX, 28, p. 588.

atoms themselves suffer a contraction we cannot doubt from the evidence that they have brought forward that the chemical attraction between atoms is one of the deciding factors as to the distance apart of these atoms when combined into a molecule. That is to say, the distance apart of the atoms is some function of the chemical affinity. The problem is as yet too complicated to permit of finding the law of the attraction, and at present we must limit ourselves to the statement that the inverse square law of the distance is possible also with this force. When Newton discovered the law of gravitation others at once seized upon that law as a possible explanation of chemical affinity. Newton himself showed that the chemical attraction decreased more rapidly with the distance than was required by the inverse square law. But if the chemical attraction is mutually absorbed or canceled by the attracting particles, then it again becomes possible that the force itself varies inversely as the square of the distance from any particular atom, itself alone considered. Moreover we know that this mutual absorption of the chemical attraction does take place.

We have made the statement that temperature has no effect upon chemical affinity. We have shown as a reason for this statement that 2.016 grams of H_2 and 16.00 grams of O_2 at the absolute zero possess at least 67984 calories of chemical energy, while the total energy necessary to raise the H_2 and the O_2 from the absolute zero to $19^\circ C$ is only 4301 calories. Now of this 4301 calories we can account for all but about 165 calories as necessitated by the changes in E_i , E_a and E_c . The details of this calculation will be given in the subsequent paper referred to above. At present we give the result only, as indicating the minute influence that temperature has upon chemical affinity. It is possible that E_i is really the differential of the chemical energy. But even if this be true, it may more reasonably be referred to a slight alteration in the distance apart of the atoms composing the molecule, than to a real alteration of the chemical affinity.

In what form can the enormous amount of energy possessed by the hydrogen and oxygen at the absolute zero exist? Clausius has shown* that no system of particles could exist in stable equilibrium if all of the energy possessed by those particles was present as kinetic energy. Nor could all of the energy exist as potential energy. The energy must be partly kinetic and partly potential. Now it can be shown that when two particles exist under a mutual attraction varying inversely as the square of the distance apart of the particles, that the system composed of these two particles, assumes the most stable equilibrium when one half of the total energy is kinetic and one half is potential. We cannot but believe it probable, that in a system of particles a similar distribution of energy would take place. The enormous amount of chemical energy that is existent at the absolute zero of temperature must, it seems to us, be present, one half as potential and one half as kinetic energy. That is to say, the hydrogen atoms and oxygen atoms at the absolute zero would revolve in pairs around a common center of gravity with enormous velocity, held in their orbits by the chemical attraction. This conception seems to us quite sufficient to explain the repulsive tendency referred to by Richards in his fourth paper above cited. We shall deal with this subject more fully later. We would only remark that the above conception of the mechanism of chemical affinity introduces no new assumption, save that the attraction obeys the inverse square law. This being true the other results follow if the principles underlying mechanics be true.

Our statement concerning the magnetic and electrical forces, not being the subject of dispute, may be passed over without comment.

As regards the gravitational force we meet the first and only exceptions to a complete similarity between the forces. The gravitational attraction is supposed not to be absorbed or neutralized by the attracting particles.

*See Myer—Kinetic Theory of Gases, p 844.

The questions involving the nature and laws of the attractive forces cannot, we are well aware, be settled by any appeal to our minds as to the relative difficulty or ease of the conception, But on the other hand such an appeal is *not without value*. If in the last analysis the testimony of consciousness cannot be trusted we had just as well give up the search for truth. We cannot hope to attain to any absolute knowledge or full conception of any of the more elementary ideas such as time, space, matter, or motion. But we may attain to a partial knowledge of these ideas, and this partial knowledge, we trust, may represent the reality truly, so far as it represents it at all. And in attempting to attain this partial knowledge, if one goes directly contrary to the testimony of one's mind as to the possibility or impossibility of a conception one should not forget that the process of denying the truth of the testimony of consciousness once begun, can be as legitimately extended to an absolute agnosticism, must be so extended, if one is consistent. One can refuse to examine the foundations for a house but one cannot undermine the foundations and yet continue to build the house. We do not believe therefore, that the difficulties in the conception of the action of gravitational forces can longer be be passed over as constituting no objection to the present statement of the law. Since Newton in 1682 deduced the law, all of the attempts—and they have been numerous—to formulate a sufficient cause for the law, have completely failed. The attempts have ended not only in failure to formulate a cause for the law, but in emphasizing, most distinctly, the difficulty of forming such conceptions at all.

May not the real cause of the trouble lie in the fact that scientists have been trying to explain how a force can be infinitely multiplied and absolutely unaffected by intervening matter, when force with such properties has really no existence? The line of apsides of mercury's orbit has a slight motion unaccounted for by the law of gravitation. Dr. Asaph Hall pointed out that the observations could be satisfied by chang-

ing the law of gravitation by very slightly increasing the exponent of the distance factor. May not this slight divergency, explained as an *increase* in the exponent of the denominator, be explained rather by a *decrease* in the numerator, due to a neutralization of the attraction by the attracted particles. The planets are but dots in space, and the distortion of the field of force by the attraction which they would neutralize would be extremely small.

It will be further urged that we have no evidence of any shielding action in the case of gravitational forces and that, besides, gravitation is proportional to mass and not to surface in any way. In reply we would point out that we are dealing with a very fundamental question, and that we have, as yet, no explanation of mass. Mass is best represented perhaps by the term "inertia", but the question is what is "inertia"? Why has a molecule of lead more inertia than a molecule of aluminum? We have not, so far as the author knows, one iota of evidence, save in the suggestiveness of the periodic table of the chemical elements, that there is really more of the "ultimate material" in the molecule of lead than in the molecule of aluminum. For anything *we know* to the contrary, mass might be created at the same time as the attraction, a sort of action and reaction due to the same cause. And why this suggestion?

Because if one attempts to consider what changes must be made in the numerator factor of the forces in order to derive a common expression for all of the attractive forces, one starts with the broad idea that the force is measured by the effect which it produces. In producing this effect an opposite and equal effect must be produced on the force itself. This is according to Newton's third law of motion. Any other supposition would mean that the forces could be increased indefinitely. Force is transference of energy. We have no law as to the conservation of force but we have a law as to the conservation of energy. The amount of energy in the universe is constant. In a given time a constant amount of

energy could not produce an infinite amount of force. But this production of an infinite, inexhaustible force is exactly what the law of gravitation necessitates, if it expresses the entire truth. We repeat *that one cannot believe that one particle of matter in the universe can attract every other particle of matter in the universe and itself suffer no diminution in its power to attract yet other particles of matter and hold also that the law of the conservation of energy is true. For these two beliefs necessitate that a constant energy, in a given time should be able to produce an infinite force, and this is impossible.* We reach therefore the conclusion that the attractive force given out by a particle in a given time is definite in amount. If therefore a portion of this attraction is expended upon one particle there remains exactly an equivalent amount less to be expended on the remaining particles. *Consequently the attraction can be measured by the amount of the neutralized force.* This deduction we claim to be founded on the first law of thermodynamics, the conservation of energy. Now the amount of attractive force which can be neutralized will vary inversely as the square of the distance apart of the particles, because the surface front of the attractive wave of force increases as the square of the distance apart of the particles and its intensity must correspondingly diminish, since the force cannot be indefinitely multiplied. We can therefore write, attractive forces are measured by,

$$\frac{\text{amount of attraction neu-}}{\text{tralized at unit distance}} \left\} \times \left\{ \frac{\text{amount of attraction neu-}}{\text{tralized at unit distance}} \right. \right. \\ d^2$$

Examining the numerator of the above fraction, there appears nothing improbable as regards its application as a general expression to take the place of the first four forces given in the table,—chemical, molecular, magnetic, and electrical. As regards gravitational force it makes mass proportional to the amount of attraction absorbed at unit distance. Is this idea necessarily wrong?

We doubt if the idea is necessarily opposed to established

astronomical data. We might suggest that one reason why no shielding action had been detected among the heavenly bodies was because the mass really did vary with the amount of the shielding and exactly canceled the effect produced. Whether the idea is supported by molecular phenomena is more a subject of doubt. It might possibly explain the increased specific heat of a solid and liquid as compared with the corresponding vapor. We will return to this point in a later paper.

Chemical, magnetic, and electrical forces show decided evidence of directive action. We distinguish, moreover, positive and negative electricity, positive and negative poles of a magnet, and positive and negative elements, as indicating some difference in the kind of attractive force which they exert. As evidence of variation in the intensity of the molecular forces with their spatial relation around the molecule, might be cited the phenomena of crystalline form, of water of crystallization and molecular combinations in general, and also those cases where a liquid appears to show a definite and symmetrical structure. The evidence is not convincing, nor is there evidence indicating positive and negative molecular attraction. With gravitational forces similarly, there is no evidence showing directive, or positive and negative tendencies, unless the earth's magnetic field should be such an evidence.

The exceedingly close relationship between the electrical and chemical forces have often suggested their identity. The close relationship between electrical and magnetic forces is also recognized. There is also some evidence that molecular attraction is closely connected with electrical phenomena. Thus it has been pointed out by Abegg that liquids which cause dissociation are themselves most associated. We would note further a correspondence between the amount of dissociation produced by a liquid on a dissolved substance and the size of the molecular attraction μ' , as obtained by us. Perhaps it is also not without significance that the metals are

the best conductors of electricity, are monatomic, and have a very great cohesion.

The amount of the molecular attraction, and the greater or less interpenetration of the molecular attraction among other molecules before it is neutralized, may, it seems to us, be the determining factor in the elasticity, ductility, malleability, brittleness, and hardness of substances in general, and of metals more particularly.

Our knowledge at present, is hardly sufficient to warrant speculation regarding the ultimate cause and nature of the attractive forces. They may be one and the same force,—the molecular attraction being the unneutralized portion of the chemical attraction, magnetic attraction being a manifestation of the latter, and electricity closely connected with the former. Gravitation would be the unneutralized portion of the molecular attraction. We consider it possible that the attractive forces are one and the same force manifested under different conditions.. We consider it likely that all of the forces are produced by some interaction between matter and ether. We consider it highly probable that the forces obey the same law whether their ultimate cause and identity be the same or not. We hope to develop the subject further in later papers.

Summary. 1. The evidence that the molecular attraction varies inversely as the square of the distance apart of the molecules, and does not vary with the temperature, is reviewed and strengthened.

2. It is pointed out that the molecular attraction must be neutralized by the attracting molecules.

3. It is shown that the equation deduced by Helmholtz in 1854, to represent the energy given out by the contraction of the sun will, by changing the constant, represent accurately the energy given out by isopentane and other substances in changing from a saturated vapor to a liquid.

4. It is shown that a large amount of chemical energy is possessed by hydrogen and oxygen at the absolute zero, and

that this energy is probably existent half as potential, half as kinetic, energy.

5. It is shown that chemical attraction is probably unaffected by temperature.

6. The idea is introduced that the attractive forces, whatever their nature, whether chemical, molecular, magnetic, electrical, or gravitational, which proceed from a particle, are definite in amount. If this attraction is exerted upon another particle the amount of the attraction remaining to be exerted upon other particles is diminished by an exactly equivalent amount.

7. The laws governing attractive forces are compared and it is suggested that all of the forces really obey the same law, viz.—the attractive forces are measured by the amount of the attraction neutralized, which is

$$\frac{\text{amount of attraction neutralized at unit distance}}{d^2} \times \frac{\text{amount of attraction neutralized at unit distance}}{d^2}$$

8. The idea that the gravitational attraction of a particle could remain undiminished regardless of the amount of the attraction exerted upon other particles is shown to be contrary to the law of the conservation of energy.

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THE FOUNDATIONS OF GEOMETRY.

BY ARCHIBALD HENDERSON, PH.D.

The study of the historical development of mathematics, and in particular the study of geometry, leads one to the conclusion that the great roles in the drama of science have been played by two inter-related, yet widely differing, forces—intuition and logic. Huxley once laughingly said of Herbert Spencer that his idea of tragedy was a deduction killed by a fact. Some of the greatest parts in the drama of science have been played by intuition; but that drama becomes a tragedy when intuitional prevision is annihilated by the inexorable irony of fact. The most epoch-making discoveries find their origin in the fortunate conjunction of intuition and experience. And the whole history of science is the history of the struggle of man's intuition, fortified by experience, to read the inscrutable riddle of Nature.

I venture to assert that nowhere is this struggle more succinctly and definitively illustrated than in the story of man's effort to formulate the hypotheses which constitute the foun-

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dations of geometry. For precise reasons, the names of Euclid and Newton stand above all other names in the *fast* of mathematics; and the reasons are strikingly similar in the two cases. In writing of *The Wonderful Century*, the nineteenth, Alfred Russel Wallace says of all time before the seventeenth century: "Then, going backward, we can find nothing of the first rank except Euclid's wonderful system of geometry, perhaps the most remarkable mental product of the earliest civilizations." In modern times, Newton's colossal figure occupies the centre of the stage, looming large, as he himself explained, because he stood upon the shoulders of giants. Like Euclid, his claim to pre-eminence rests less upon the discovery of new principles than upon the immeasurably greater service of the universal formulation and grounding of mathematics. Newton brought all natural phenomena under the reign of universal law, Euclid reduced all geometrical knowledge to system.

"It is certain," says Philip Kelland, "that from its completeness, uniformity and faultlessness, from its arrangement and progressive character, and from the universal adoption of the completest and best line of argument, Euclid's *Elements* stand pre-eminently at the head of all human productions. In no science, in no department of knowledge, has anything appeared like this work: for upwards of 2,000 years it has commanded the admiration of mankind, and that period has suggested little toward its improvement." Indeed it is no cranky enthusiasm, but absolute conviction that prompts the mathematician to say that geometry is ultimately fundamental for the progress of science and the advancement of humanity. It is continually bringing to pass those epoch-making events in the history of science whereby what one day seems to be the purest science becomes the next a vitally important piece of applied science. Such events enable us to realize that pure science and utilitarian science are not differentiable, but at bottom and in essence one and the same thing. "I often find the conviction forced upon me," said the brilliant English

geometer H. J. S. Smith, "that the increase of mathematical knowledge is a necessary condition for the advancement of science, and, if so, a no less necessary condition for the improvement of mankind. I could not augur well for the enduring intellectual strength of any nation of men, whose education was not based on a solid foundation of mathematical learning, and whose scientific conceptions, or, in other words, whose notions of the world and of the things in it, were not bound and girt together with a strong framework of mathematical reasoning."

In that charming book, cast in the dialogue form and entitled *Euclid and his Modern Rivals*, by the Rev. Charles L. Dodgson, the brilliant "Lewis Carroll" of *Alice in Wonderland* fame, Euclid confesses with reluctance that some secret flaw lies at the root of the subject of parallel lines. Probabilities, not certainties, are all that he has in vindication of his belief. Here we lay our fingers on the rift in the lute; in this confession, we catch a glimpse of that *ignis fatuus* that mathematicians have pursued in vain for well-nigh two thousand years. Professor G. B. Halsted cites Sohncke* as saying that in mathematics there is nothing over which so much has been spoken, written, and striven, as over the theory of parallels, and all, so far (up to his time), without reaching a definite result and decision. It is impossible, says the great Poincaré, to imagine the vast effort wasted in this chimeric hope, this evanescent dream. Indeed, it was not until the nineteenth century that the truth began to dawn upon the minds of men; and almost simultaneously from the distant frontiers of Europe, at Kazan on the Volga and at Maros-Vasarhely in far Erdély, there came the startling generalizations that have tended to revolutionize our conceptions of geometry, and thrown doubts upon the very nature of the space in which we live.†

**Encyclopædie der Wissenschaften und Kunst*; Von Ersch und Gruber, Leipzig, 1838, under "Parallel."

†Compare *The Value of Non-Euclidian Geometry*, by G. B. Halsted; Pop. Sci. Monthly, vol. 67, pp. 639-646. At the outset, I wish to acknow-

In order to make the matter clear to "the man in the street," it is necessary to speak, not so much as a mathematician as one who knows, let us say, no more of mathematics than is taught in the Freshman year in the college or university. We recall that Euclid uses three terms in laying the foundations for his geometry: *Definitions* (ὅμοι), *Postulates* (αἰτήματα), and *Common Notions* (κοινὰ εννοιαί). He defined his elements: point, line, etc.; he assumed that you can draw a straight line from one point to another; and he laid down as accepted such statements as "Things equal to the same thing are equal to each other," etc. For Euclid's *Common Notions* later geometers substituted the unfortunate term—unfortunate, as we shall subsequently see—*Axioms*. This word Axiom (Greek, ἀξίωμα) is used by Aristotle to mean "a truth so obvious as to be in no need of proof"—virtually in the modern sense of a "self-evident truth." Euclid used only five Postulates and thirteen Common Notions, none of which challenged doubt save the celebrated "parallel-postulate." Indeed, all were very simple except this fifth postulate,* which excited suspicion, not only on account of its cumbrous form, but because it is used only once—to prove the inverse of a proposition already demonstrated—the seventeenth. "It requires," says Staeckel, "a certain amount of courage to declare such a requirement, alongside the other simple axioms and postulates." The Swiss mathematician, J. H. Lambert,† averred that Proklos, Euclid's first commentator (410–485 A. D.) argued that the parallel-postulate was demonstrable, because it was the inverse of the seventeenth proposition. Euclid's twenty-seventh proposition: that straight lines

ledge my general indebtedness to the writings of Professor Halsted, to which I occasionally refer.

*Also given in various editions of Euclid as a Common Notion—eleventh, twelfth, or thirteenth.

†Lambert's *Theory of the Parallel Lines* was not published until 1786 twenty years after it was written and nine years after his death, by Bernouilli and Hindenberg in the *Magazin für die reine und angewandte Mathematik*.

making with a transversal equal alternate angles are parallel, is easily demonstrated. But in order to prove its inverse: that parallels cut by a transversal make equal alternate angles, he is forced to resort to the following postulate axiomatically stated (Williamson's translation, Oxford, 1781):

11. *And if a straight line meeting two straight lines makes those angles which are inward and upon the same side of it less than two right angles, the two straight lines being produced indefinitely will meet each other on that side upon which the angles are less than two right angles (Fig. 1, Angle $A + \text{Angle } B$ less than 180°).*

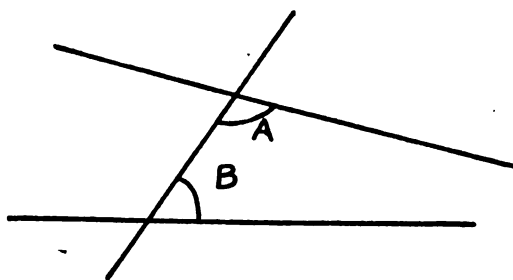


FIG 1.

The points to be observed in connection with this postulate are two in number. First, "no one had a doubt of the external reality and exact applicability of the postulate. The Euclidian geometry was supposed to be the only possible form of space-science, that is, the space analyzed in Euclid's axioms and postulates was supposed to be the only non-contradictory sort of space." Second, the postulate was neither so axiomatic nor so simple as the proposition it was used to prove; and hence the world of mathematicians concluded, with Proklos, that this postulate could be deduced as a theorem from the other assumptions and the twenty-eight preceding theorems. And so, for hundreds and hundreds of years, the

mathematical world exhausted itself in the effort to prove Euclid's celebrated parallel-postulate. Ptolemy, the great astronomer, wrote a treatise purporting to prove it; and Nasir Eddin (1201-1274), whose work on Euclid in Arabic was printed at Rome in 1594, sought to dispense with the problem of parallelism, by taking his stand upon another postulate: that two straight lines which cut a third straight line, the one at right angles, the other at some other angle, will converge on the side where the angle is acute, and diverge where it is obtuse. Other mathematicians, notably John Wallis whom I claim as an ancestor, sought to turn the flank of the difficulty by identifying the problem of parallels with the problem of similitude. In general, we may say that the problem was attacked from three sides.

First, there were those who sought to substitute a new definition of parallels for Euclid's, which reads (I, Def. 35):

"Parallel straight lines are such as are in the same plane, and which being produced ever so far both ways do not meet."

To cite a few classic definitions, Wolf, Boscovich, and T. Simpson use the following: "Straight lines are parallel which preserve the same distance from each other." But this is begging the question, as Halsted has remarked, since it assumes a *definition*, viz.: "Two straight lines are parallel when there are two points of the one on the same side of the other from which the perpendiculars to it are equal;" and at the same time assumes a *theorem*: "All perpendiculars from one of these lines to the other are equal." Those geometers who assume that parallel lines have the same direction are guilty of a *petitio principii*, in assuming (Varignon and Bezout) the *definition* that "parallel lines are those that make equal angles with a third line," and also in assuming the *theorem* that "Straight lines that make equal angles with one transversal make equal angles with all transversals."

The second method of attack, far more logical, was to pro-

pose a substitute for the parallel-postulate, such as "Two straight lines which intersect cannot *both* be parallel to the same straight line" (Ludlam), and "Any three points are collinear or concyclic" (Bolyai). And the celebrated Hilbert, in his *Vorlesung ueber Enklidische Geometrie*, (winter semester, 1898-9) cites the following theorems:

1. The sum of the angles of a triangle is always equal to two right angles.
2. If two parallels are cut by a third straight line, then the opposite (corresponding) angles are equal.
3. Two straight lines, which are parallel to a third, are parallel to each other.
4. Through every point within an angle less than a straight angle, one can always draw straight lines which cut both sides (not perhaps their prolongations).
5. All points of a straight line have from a parallel the same distance.

His comment is, "Finally we remark, that it seems as if each of these five theorems could serve precisely as the *equivalent of the Parallel Axiom*."

The third class of investigators consisted of those geometers who foundered upon the rock of the attempt to deduce Euclid's parallel-postulate from reasonings about the nature of the straight line and the plane angle, helped out by Euclid's other assumptions and his first twenty-eight theorems. Euclid took pains to prove things which were more axiomatic by far—for instance, that the sum of two sides of a triangle is greater than the third side—a thing which any ass knows. To give one illustration of the many so-called proofs, take the most plausible one, exposed by Charles L. Dodgson, in his *Curiosa Mathematica*, Part I. pp. 70-71, 3rd edition, 1890:

"Yet another process has been invented—quite fascinating in its brevity and its elegance—which, though involving the

same fallacy as the Direction-Theory, proves Euc. I, 32. without even mentioning the dangerous word 'Direction'.

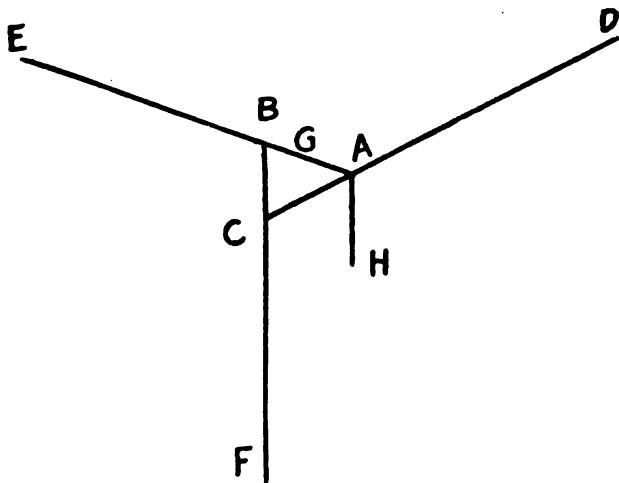


FIG. 2.

"We are told to take any triangle ABC; to produce CA to D; to make part of CD, viz., AD, revolve, about A, into the position ABE; then to make part of this line, viz., BE, revolve, about B, into the position BCF; and lastly to make part of this line, viz., CF, revolve, about C, till it lies along CD, of which it originally formed a part. We are then assured that it must have revolved through four right angles: from which it easily follows that the interior angles of the triangle are together equal to two right angles.

"The disproof of this fallacy is almost as brief and elegant as the fallacy itself. We first quote the general principle that we can not reasonably be told to make a line fulfil *two* conditions, either of which is enough by itself to fix its position: e. g., given three points X, Y, Z, we can not reasonably be told to draw a line from X which shall pass through Y *and* Z; we can make it pass through Y, but it must then take its chance of passing through Z; and *vice versa*.

"Now let us suppose that, while one part of AE, viz., BE, revolves into the position BF, another little bit of it, viz., AG, revolves, through an equal angle, into the position AH; and that, while CF revolves into the position of lying along CD, AH revolves—and here comes the fallacy.

"You must not say 'revolves through an equal angle, into the position of lying along AD,' for this would be to make AH *fulfil two conditions at once*.

"If you say that the one condition involves the other, you are virtually asserting that the lines CF, AH are equally inclined to CD—and this in *consequence* of AH having been so drawn that these same lines are equally inclined to AE.

"That is, you are asserting, 'A pair of lines which are equally inclined to a certain transversal, are so to any transversal.' [Deducible from Euc. I, 27, 28, 29]."

Thousands of mathematicians have tried in vain to prove something that only a genius could see was indemonstrable. The history of the evolution and exfoliation of that fertile idea is of very great interest to the mathematician of today, especially in view of the fact that beyond contradiction the most original researches of the last quarter of the nineteenth century pertain to the non-Euclidian geometry.

The most notable attempt to demonstrate Euclid's parallel-postulate that has been preserved to the world is embodied in a book entitled *Euclid Vindicated from every Blemish*, by a Jesuit priest named Hieronymus Saccheri (1667-1773).^{*} He was in close association with the great Italian geometer Giovanni Ceva (through his brother Tommaso), whose name a celebrated theorem bears; and by purely geometrical methods in Euclidian style, he sought to apply the *reductio ad absurdum* method to the problem of the parallel-postulate. His method is essentially as follows: At the end-points of a sect AB erect two equal perpendiculars AC and BD on the

^{*}*Euclides ab omni naevo vindicatus; sive conatus geometricus quo stabiluntur prima ipsa universae geometricae principia. Auctore Hieronymo Saccherio Societatis Jesu, Mediolani.*

same side of AB. Join C and D by a straight line; and it easily follows that the angle ACD is equal to the angle BDC. Now there are three possibilities: (1) The angle ACD is acute; (2) the angle ACD is obtuse; (3) the angle ACD is a right angle. He undertook to prove the absurdity of the first two possibilities so as to leave only the third possibility, viz., that the two angles ACD and BDC are each right angles. He pursued the lines of argument, following from the first two assumptions, at some length—for his book was more than a hundred pages long; but was doubtless amazed to discover that for quite a time he was unable to involve himself in any logical contradiction. In the event, certain of his conclusions were erroneous, and led him to believe that he had actually proved the parallel-postulate. What he really did do was to identify the assumption of the right angle with the parallel-postulate, thus showing the two to be mutually interchangeable postulates.

In 1766, Johann Heinrich Lambert wrote his theory of parallel lines, in which he starts from the notion of the sum of the angles of a triangle being equal to 180 degrees. If the sum is equal to 180 degrees, the triangle is a figure in a plane; if the sum is greater than 180 degrees, the triangle is on a sphere; if the sum is less than 180 degrees, the triangle is on the surface of an imaginary sphere (radius equal to the square root of minus one)—Lobatchevsky—Bolyai “imaginary geometry,” so called because its trigonometric formulas are those of the spherical triangle if its sides are imaginary. As to the third hypothesis, Lambert naïvely said: “There is something attractive about this which easily suggests the wish that the third hypothesis might be true.”*

France contributed little to the solution of the problem; recognition, however, should be given to Legendre, who stud-

*Compare *The Philosophical Foundations of Mathematics*, by Dr. Paul Carus; *The Monist*, vol. 18, pp. 278-294; 370-397; 498-522, to which I am indebted. I once had the pleasure of hearing Dr. Carus lecture on this subject before the Mathematical Club of the University of Chicago.

ied the problem all his life. By the aid of the principle of continuity, the so-called Theorem of Archimedes, he did prove two well known theorems:

1. In a triangle, the sum of the three angles can never be greater than two right angles.
2. If the sum of the three angles is equal to two right angles in one triangle, it is equal to two right angles in every triangle.

But Euclid's geometry can be built up without the continuity assumption; and only a short time ago, there was proved by Dehn, something that might have been inferred, viz., that Legendre's first theorem does not hold, i. e. not without the continuity assumption.*

In addition to Legendre, there was one other Frenchman, Joseph Lagrange, France's greatest mathematician in his day, who attempted to prove Euclid's parallel-postulate. Toward the end of his life, so the story runs, Lagrange composed a discourse on parallel lines. He began to read it in the Academy, but suddenly stopped, and, in confusion, stammered: "Il faut que j'y songe encore"—"I'll have to think about it a while longer." He stuck his manuscript in his pocket, sat down, and never recurred to the subject.

The first distinct epoch in the history of the non-Euclidian geometry begins with the time of the great German mathematician, Karl Friedrich Gauss. He is in no sense entitled to credit as a discoverer in this line, although for many years he occupied himself with the problem. The researches he claims to have made on the subject have not come down to us; but he was closely associated, according to abundant testimony, with Schweikart and Bolyai, two of the three independent discoverers of the non-Euclidian geometry. The publication in 1900 of the eighth volume of Gauss' *Collected Works* shows, from a letter to Bolyai, the elder, a Hungarian mathe-

*Compare *The Foundations of Geometry*, by David Hilbert; Translation by E. J. Townsend, Open Court Publishing Co., Chicago.

matician, that in 1779 Gauss was still hopelessly attempting to prove that Euclid's was the only non-self-contradictory system of geometry, and also the system of our space. Bolyai, the elder, submitted to Gauss, in 1804, a pseudo-proof of the parallel-postulate, but Gauss immediately detected the fallacy. When Bolyai, the elder, submitted a second pseudo-proof to Gauss, in 1808, he never replied. Bolyai's words, accompanying one of these pseudo-proofs, are pathetic in their earnestness and yearning: "Oft have I thought, gladly would I, as Jacob for Rachel, serve in order to know the parallels founded even if by another. Now just as I thought it out on Christmas night, while the Christians were celebrating the birth of the Saviour in the neighboring church, I wrote it down yesterday, and I send it to you enclosed herewith."

On November 23, 1823, Bolyai the son, called Janos, wrote a letter to his father, professor of mathematics at Maros-Vasarhely, in which he announces his discovery of the non-Euclidian geometry—a letter full of youthful fire and enthusiasm, from which I quote:

"I intend to write, as soon as I have put it into order, and when possible to publish, a work on parallels. At this moment it is not yet finished, but the way which I have hit upon promises me with certainty the attainment of the goal, if it in general is attainable. It is not yet attained, but I have discovered such magnificent things that I myself am astounded at them.

"It would be damage eternal if they were lost. When you see them, father, you yourself will acknowledge it. Now I cannot say more of them, only so much: *that from nothing I have created another wholly new world.* All that I have hitherto sent you compares to this only as a house of cards to a castle."*

His results were printed as an *Appendix* to his father's work, entitled *Tentamen Juventutem Studiosam in Elementa Matheseos Puræ, Elementaris ac Sublimioris, Methodo Inventiva, Evidentiâ—que huic Propria Introducendi*. The two dozen pages contributed by the younger Bolyai have been some-

**The Science Absolute of Space*, by John Bolyai, translated by G. B. Halsted; Introduction, pp. XXVII, XXVIII.

what exaggeratedly characterized as the most remarkable two dozen pages in the history of thought. When this work at last reached Gauss, he wrote to his pupil and friend, Gerling: "I hold this young geometer von Bolyai to be a genius of the first magnitude." Bolyai called his work, *The Science Absolute of Space, independent of the truth or falsity of Euclid's Axiom XI (which can never be decided A PRIORI)*. And later, we read on the title page of the elder Bolyai's *Kurzer Grundriss*: "the question, *whether two straight lines, cut by a third, if the sum of the interior angles does not equal two right angles, intersect or not?* no one on the earth can answer without assuming an axiom (as Euclid the eleventh)." The work of Bolyai, the younger, which makes all preceding space only a special case, only a species under a genus, and requiring a descriptive adjective *Euclidian*, was rescued from oblivion, after thirty years, by Professor Richard Baltzer, of Dresden; and J. Hoüel, of Bordeaux, following in the steps of Baltzer, inserted extracts from Bolyai's book in his *Essai Critique sur les principes fondamentaux de la Geometrie elementaire*. Indeed, this scientist mastered the principal European languages in order to make known to his contemporaries the most celebrated mathematical works.

There is another name which deserves to become conspicuous in the history of non-Euclidian geometry; but not until 1900 were the facts in connection with his independent discovery accurately known. In a letter to the elder Bolyai, written October 31, 1851, Gerling, a scholar of Gauss and Professor of Astronomy at Marburg, wrote as follows: "We had here about this time (1819) a law professor Schweikart, who had attained to similar ideas, since without help of the Euclidian axiom he developed in its beginnings a geometry which he called Astralgeometry. What he communicated to me thereon I sent to Gauss, who then informed me how much farther already had been attained on this way, and later also expressed himself about the acquisition, which is offered to the few expert judges in the Appendix to your

book." On the publication of volume 8 of Gauss's *Collected Works*, in 1900, light is at last thrown upon Schweikart's discovery. Here we find Gerling's actual letter to Gauss, written in 1819, in which he says, among other things: "Apropos of the parallel-theory, ... I learned last year that my colleague Schweikart had written on parallels He said that he was now about convinced that without some datum the Euclidian postulate could not be proved, also that it was not improbable to him that our geometry is only a chapter of a more general geometry."* Enclosed in this letter was a paper by Schweikart, dated Marburg, December, 1818. From this we learn:

"There is a two-fold geometry—a geometry in the narrower sense—the Euclidian, and an astral science of magnitude.

"The triangles of the latter have the peculiarity, that the sum of the three angles (of a triangle) is not equal to two right angles.

"This presumed, it can be most rigorously proven:

(a) That the sum of the three angles in the triangle is *less* than two right angles;

(b) That this sum becomes ever smaller, the more content the angle encloses;

(c) That the altitude of an isoscles right angled triangle indeed ever increases, the more one lengthens the side; that it, however, cannot surpass a certain line, which I call the *constant*."

It can be easily proved that if this constant is infinitely great, then, and then only, is the sum of the three angles of every triangle equal to two right angles.

That the doctrine made converts in high places is evidenced by Bessel's letter to Gauss, Feb. 10, 1829: "Through that which Lambert said, and what Schweikart disclosed orally, it

**Gauss and the non-Euclidian Geometry*, by G. B. Halsted; Science, N. S. Vol. XII, No. 309, pp. 842-846, Nov. 30, 1900.

has become clear to me that our geometry is incomplete, and should receive a correction, which is hypothetical, and if the sum of the three angles is equal to one hundred and eighty degrees, vanishes.

"That were the *true* geometry, the Euclidian, the *practical*, at least for figures on the earth."*

The third name most closely associated in the popular mind with the discovery of the non-Euclidian Geometry is that of Nicolai Ivanovich Lobatchevsky. This brilliant genius, afterwards dubbed by Hoüel the modern Euclid, was born in the year 1793 near Nijni Novgorod on the Volga. He studied under the great Bartels, was graduated with distinction, became professor of mathematics, and finally rector, of the University of Kazan. The manuscripts of certain of his works were lost, but fortunately there remains the world-famous *Geometrical Researches on the Theory of Parallels*.† While both Gauss and Lobatchevsky were students of Bartels, there is even less reason to believe that Gauss contributed to Lobatchevsky's, than that he assisted in Bolyai's, discovery of the non-Euclidian geometry. In his *New Elements of Geometry*, we find Lobatchevsky's clear enunciation:

"The futility of the efforts which have been made since Euclid's time during the lapse of two thousand years awoke in me the suspicion that the ideas employed might not contain the truth sought to be demonstrated. When finally I had convinced myself of the correctness of my supposition I wrote a paper on it (assuming the infinity of the straight line).

"It is easy to show that the straight lines making equal angles with a third never meet.

"Euclid assumed inversely, that two straight lines unequally inclined to a third always meet.

"To demonstrate this latter assumption, recourse has been had to many different procedures.

**The Philosophical Foundations of Mathematics*, by Paul Carus; The Monist, vol. 13. p. 280.

†Compare the English translation by G. B. Halsted, published by the University of Texas, Austin, 1891.

"All these demonstrations, some ingenious, are without exception false, defective in their foundations and without the necessary rigor of deduction."

Lobatchevsky classifies all the co-planar lines through a given point A with reference to another co-planar line BC not passing through A, under two heads—cutting and non-cutting (Fig. 3). The transition from the non-cutting lines,

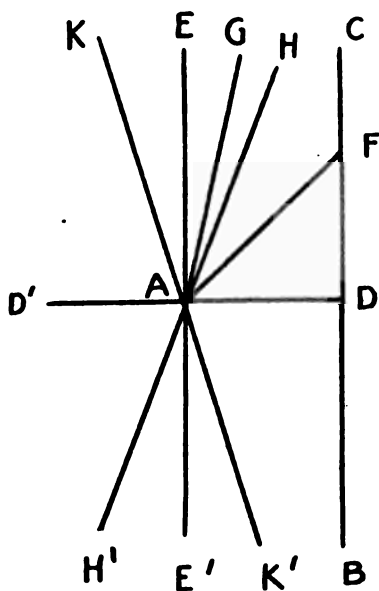


FIG 3.

such as EA and GA, to the cutting lines, such as FA, is marked by one line HA—the boundary line between the two classes; this he entitles the *parallel line*. From the assumptions, there arises the necessity of making a distinction of *sides in parallelism*, and hence there must be two parallels, so-called, one on each side. One logical consequence of this is that "if in any rectilineal triangle the sum of the three angles is equal to two right angles, this is also the case for every triangle"—one instance is the criterion for all.

As Poincaré, perhaps the world's greatest living mathematician, recently said, in his review of Hilbert's *Grundlagen der Geometrie*:

"Lobachevski succeeded in building a logical edifice as coherent as the geometry of Euclid, but in which the famous postulate is assumed false, and in which the sum of the angles of a triangle is always less than two right angles. Riemann devised another logical system, equally free from contradiction, in which the sum is, on the other hand, always greater than two right angles. These two geometries, that of Lobachevski and that of Riemann, are what are called the *non-Euclidian Geometries*. The postulate of Euclid then cannot be demonstrated; and this impossibility is as absolutely certain as any mathematical truth whatsoever."*

Limits of space forbid more extended treatment of the work of Schweikart, of Bolyai, and of Lobatchevsky. By no means secondary in interest to the investigations of these men are the researches of Riemann upon the Elliptic Geometry; Cayley's projective theory of measurement, and the Absolute, leading through Klein to the non-Euclidian geometry; the hypotheses advanced by Clifford to explain the nature of the space in which we live; the popular expositions of Helmholtz; and Lie's great group-theoretic structure built upon the hypothesis of *Zahlenmannigfaltigkeit*. Nor can I enter, at this place, into any discussion of the recent movement toward the treatment of geometry as a whole from the purely synthetic standpoint, inaugurated by Pasch, carried on by Peano, Pieri, and Veronese, and crowned by the masterly work of Hilbert. These modern investigators in what has been fittingly termed *abstract mathematics* have exhibited the potency of symbolism in removing from attention the

*Compare *The Value of Non-Euclidian Geometry*, by G. B. Halsted; Pop. Sci. Monthly, vol. 67, pp. 642-3.

concrete connotations of the ordinary terms of general and mathematical language. And yet, as Professor E. H. Moore has pertinently suggested, "the question arises whether the abstract mathematicians in making precise the metes and bounds of logic and the special deductive sciences are not losing sight of the evolutionary character of all life-processes, whether in the individual or in the race. Certainly the logicians do not consider their science as something now fixed. All science, logic and mathematics included, is a function of the epoch—all science, in its ideals as well as in its achievements..... One has then the feeling that the carrying out in an absolute sense of the program of the abstract mathematicians will be found impossible. At the same time, one recognizes the importance attaching to the effort to do precisely this thing. The requirement of rigor tends toward essential simplicity of procedure, as Hilbert has insisted in his Paris address, and the remark applies to this question of mathematical logic and its abstract expression."*

Perhaps a not unnatural confusion may arise in the mind of the layman in regard to the ultimate meaning, the far-reaching significance of these discoveries. As Artemus Ward used to say, "Why this thusness?" Indeed so revolutionary have many of the new theories and discoveries appeared that their authors, in more than one instance, have hesitated long before giving them to the world. The pioneers in science sometimes dread, not inadvisedly, the possibility that their startling and epoch-making hypotheses and investigations may lead them to be dubbed sensationalists and fakirs. Compare, for example, the letter Gauss wrote to Bessel, Jan. 27, 1829:

"I have also in my leisure hours frequently reflected upon another problem, now of nearly forty years standing. I refer to the foundations of geometry. I do not know whether I have ever mentioned to you my views on this matter. My meditations have also taken

**On the Foundations of Mathematics*, by E. H. Moore. Presidential address, Am. Math. Soc., Dec. 29, 1902. *Science*, March 13, 1903, pp.401-416.

more definite shape, and my conviction that we cannot thoroughly demonstrate geometry *a priori* is, if possible, more strongly confirmed than ever. But it will take a long time for me to bring myself to the point of working out and making public my *very extensive* investigations on this subject, and possibly this will not be done during my life, inasmuch as I stand in dread of the clamor of the Boeotians, which would be certain to arise if I should ever give *free* expression to my views."

As that wayward Irishman, Bernard Shaw, has said, the prime and indispensable quality of the pioneer must be his willingness to make a fool of himself—at first! And it matters not in what sphere, whether art, literature or science, the great thing, as Henrik Ibsen says, is not to allow one's self to be frightened by the venerableness of the institution.

Now that the truth in regard to many of the mooted questions which pertain to the foundations of geometry has at last been daringly disclosed, the first question that naturally arises is: Has Euclid's fame suffered by the discovery? One might be led to think so if dependence were to be placed in Clifford's characterization of Lobatchevsky's celebrated monograph as "Euclid without the vicious assumption." Such a remark is not only misleading: it displays a fundamental misapprehension in regard to the Euclidian and non-Euclidian geometries. The real truth of the matter is that Euclid's genius today shines forth more resplendently than ever; the almost flawless perfection of his work is only thrown into clearer perspective and higher relief. From the purely philosophical, the metaphysical point of view, the discovery of the non-Euclidian geometry is of vast interest; for it gives rise to endless speculations in regard to the character of space—even of inter-stellar space. Are the three angles of a triangle equal to two right angles if the sides of the triangle are the distances from the earth to the remotest fixed star? In the realization that Euclidian geometry is only a chapter in a more general geometry, fitly entitled Pan-Geometry, and the consequent almost infinite extension of the domain of research consists the great value of the discovery to the mathemati-

cian. Most interesting comparisons between the different types of geometry flow from a study of certain surfaces. Since the sum of the three angles of a spherical triangle is greater than two right angles, it is evident that the characteristic geometry of the sphere is Riemannian; it has been known, since Lobatchevsky and Bolyai, that the characteristic geometry of the orisphere is Euclidian; since Beltrami, that of the Euclidian pseudo-sphere is Lobatchevskian.* Such generalizations as Barbarin's Theorem, for example, link together the various types of geometry in a most succinct and illuminative fashion, exhibiting with great clarity their fundamental distinctions and similarities. Text books in non-Euclidian geometry are now being written; Professor Halsted entitles a popular article *The Non-Euclidian Geometry Inevitable*. The first step toward the popularization of non-Euclidian geometry is the clear enunciation, at the proper place in our ordinary text-books of geometry, of the principle on which the Euclidian geometry rests: that from the standpoint of pure logic the parallel-postulate is a mere choice between alternatives. "In all the books put into the hands of students," as M. Barbarin has said, "the hypothetical and wholly factitious character of the Euclidian postulate (should) be put well into relief."†

The second great gain from the discovery of the non-Euclidian geometry is the possibility of the formulation of the principles of the general geometry. It is most instructive and stimulating to the mathematical student to see the theories of Euclidian geometry emerge as special cases of the more general and comprehensive theories of Pan-Geometry. The

*If we consider the tubes or surfaces equidistant from a straight line, and make that distance infinite, we have the orispheres; the pseudo-spheres are surfaces of revolution which have for meridians a tractrix or line of equal tangents. A pseudo-sphere finds its approximate counterpart in nature in a morning-glory whose stem is infinitely prolonged; for a figure, cf. *Elements of Trigonometry*, by Phillips and Strong, p. 126.

†*On the Utility of Studying Non-Euclidian Geometry*, by P. Barbarin; *Le Mathematique*, May, 1901.

general geometry contains many propositions common to all the systems, which should be enumerated in the same terms in each of these. Sometimes a modification in the form of statement, veiling the special property of the figure in the particular type of space, would result from a generalization of the theorems for the general geometry, in which case such special properties should be clearly indicated. Thus, to state an illustration cited by M. Barbarin,* that of the convex quadrilateral inscribed in a circle, in Euclidian geometry, *the sum of two opposite angles is constant and equal to two right angles*; in non-Euclidian geometry, *this sum is variable*. Notwithstanding this, the two forms may be reconciled, since in both cases *the sum of two opposite angles equals that of the other two*, and this is sufficient for a convex quadrilateral to be inscriptible. Such generalizations often lead to a complete redistribution of values, and so clarify the processes of Euclidian geometry in the most distinctive way. Professor E. Study has said :

"The conception of geometry as an experimental science is only one among many possible, and the standpoint of the empiric is as regards geometry by no means the richest in outlook. For he will not, in his one-sidedness, justly appreciate the fact that in manifold, and often surprising ways the mathematical sciences are intertwined with one another, that in truth they form an indivisible whole.

"Although it is possible and indeed highly desirable that each separate part or theory be developed independently from the others and with the instrumentalities peculiar to it, yet whoever should disregard the manifold interdependence of the different parts, would deprive himself of one of the most powerful instruments of research.

"This truth, really self-evident yet often not taken to heart, applied to Euclidian and non-Euclidian geometry, leads to the somewhat paradoxical result that, among conditions to a more profound understanding of even elementary parts of the Euclidian geometry, the knowledge of the non-Euclidian geometry cannot be dispensed with."[†]

*On the Utility of Studying non-Euclidian Geometry, l. c.

†Ueber Nicht-Euklidische und Linien-Geometrie, Greifswald, 1900.

Lastly, the discovery of the non-Euclidian geometry virtually fixes upon the Euclidian geometry its practical and empirical character. "In connecting a geometry with experience," to cite the view of the most confirmed of non-Euclidians, "there is involved a process which we find in the theoretical handling of any empirical data, and which therefore should be familiarly intelligible to any scientist. The results of any observations hold good, are valid, always only within definite limits of exactitude and under particular conditions. When we set up the axioms, we put in place of these results statements of absolute precision and generality. In this idealization of the empirical data our addition is at first only restricted in its arbitrariness in so much as it must seem to approximate, must apparently fit, the supposed facts of experience, and, on the other hand, must introduce no logical contradiction. Thus to-day the ordinary triply-extended space of our experience may be purely Bolyaian, or purely Euclidian, or purely Cliffordian, or purely Riemannian."* To put it extravagantly, the non-Euclidian geometer, like a croupier, cries out to his audience: "Here are three assumptions in regard to the angle sum of a triangle; from not one of the three do any logical contradictions follow; which one will you take? *Messieurs, faites vos jeux!*" The result is, not that the mathematical world singles out one to the exclusion of the others—but studies all three, their inter-actions, inter-relations, and mutual dependencies. And yet if the "man in the street" impatiently cries out: "I am not interested in what may be the possible nature of space in the vicinity of Mars, or even the possible character of geometrical figures on the planet Jupiter, or in the tortuous reasonings of a mathematical Alice in Wonderland. Tell me, what is the character of the space I occupy, the nature of the physical world in which I live and move and have my being?" And the answer of mathematicians throughout the world, with certain distinguished exceptions,

**The Appreciation of non-Euclidian Geometry*, by G. B. Halsted; *Science*, March 22, 1901, pp. 462-465.

would doubtless be: "Although it can never be mathematically demonstrated, our space I believe to be Euclidian space because of the testimony of experience." The three angles of a triangle can never be mathematically demonstrated to be equal to two right angles; nor can experience ever give the absolutely exact metric results desiderated. And yet, this thing amounts to what we crudely call "moral certainty", viz. that the "practical geometry", as Bessel rightly called it, within reasonable limits of error—for which we must always allow in this imperfect world—and for limited portions of space, is Euclidian. So, after all, it seems that we are forced to the conclusion that the axioms of geometry, although they are, abstractly speaking, assumptions, are, practically speaking, deductions from experience. Only as suppliants at the feet of Nature herself can we ever hope to penetrate to the heart of her mystery.

A NEW COLOR TEST FOR THE LIGNOCELLULOSES.

ALVIN S. WHEELER.

The lignocelluloses give a number of color reactions, the most valuable being the reaction with phloroglucinol in hydrochloric acid solution. The rich reddish violet color is very pronounced. The salts of anilin give a golden yellow but the color is not sufficiently dark to allow them to compete with phloroglucinol. However, I have observed that the salts of the nitranilines produce a color which is very striking, a rich blood red color. As phloroglucinol solutions are said to deteriorate with age, I have kept for one year exposed to full daylight a hydrochloric acid solution of phloroglucinol and also one of paranitraniline. The phenol solution became brown, showing some decomposition and on applying it to pine sawdust the violet color was not fully developed instantly but in a few minutes became as dark as that made by a fresh solution. The nitraniline solution was perfectly stable and gave its reaction as quickly as a fresh solution. So far as a year's time is concerned the new reagent has no real advantage over the old.

The red color is produced by the salts of the ortho, meta and paranitranilines but the meta compounds are much inferior, the color being pale in comparison. The ortho and para compounds give the same deep color. Paranitraniline is to be preferred since it is more readily obtained. Different salts of this amine such as sulphate, nitrate, hydrobromide and hydrochloride were tested but no difference was noted. The hydrochloride was adopted for use. This salt, dissolved in pure water, only gives a yellow color, but on stand-

ing for some hours the red color develops. Since the best results are obtained when free acid is present, various strengths of hydrochloric acid were tried from one-half to a twelve per cent. solution but no important difference could be observed. It is convenient to use an acid of specific gravity 1.06. A study of various concentrations of the paranitraniline in acid solution revealed no differences of consequence. It was observed that in all cases hot solutions produced much quicker results than cold ones. In fact hot solutions seemed to give the full depth of color instantaneously.

The reagent was applied to a wide variety of woods, to jute, to oat straw and to many samples of paper. A No. 1 book paper showed numerous small red fibres, indicating adulteration with mechanical wood or else incomplete conversion of the lignocellulose. A yellow paper containing five per cent. of mechanical wood gave a deeper color, likewise a salmon pink paper. A very deep blue paper made of sulphite cellulose showed scattering red fibres which were easily seen. A sample of white paper made from bleached sulphite gave no trace of color.

A striking lecture experiment is carried out by projecting a quantity of the hot solution against a large sheet of paper made of mechanical wood, such as newspaper stock.

In conclusion, the reagent is made by dissolving two grams of paranitraniline in one hundred cubic centimeters of hydrochloric acid, either of specific gravity 1.06 or a 4N solution. When used hot, a blood red color is instantaneously obtained with lignocelluloses.

*University of North Carolina,
February 21, 1907.*

NOTES ON THE GEOLOGY OF CORE BANK, N. C.

BY COLLIER COBB.

The storm of October 17th, 1906, cut three inlets across Core Bank, just below Cedar Island Inlet (closed since 1805) and near the site of Old Drum Inlet (closed in 1822), and revealed the fact that the beach sands and dunes (Columbia) rest upon a clay foundation (Neocene), which in its turn is underlaid by Tertiary shell-rock, exactly similar to the shell rock occurring at various points in Currituck Sound and already noted in this Journal.* Among the forms observed here were *Turritella*, *Lunatia*, *Glycymeris*, *Tornatellaea*, *Nucula*, *Lucina*, *Corbula*, *Protocardia*, *Modiolus*, *Arca*, *Ostrea*. These were in most cases packed together in the shell-rock, and a few sharks' teeth were included. The upper portion of this rock was made up almost entirely of the shells of *Tellina*. After the storm the entire bank in the region of the new-formed inlets was black with magnetic sands, heavily ripped, their thickness being in some cases as much as three inches.

Numerous water-worn shells of *Cardium*, *Anomia*, *Exogyra*, *Serpula*, *Gryphaea*, of species identical with those found by the writer on Currituck Banks, were washed up by the storm, as were also the bones of fishes, all these being Cretaceous fossils. Many coral fragments were also found. The Captain of the Core Bank Life Saving Station, Willis, sailed through one of the inlets and found six feet of water in its shallowest part. On December 16th, 1906, I walked across all three of the inlets at low water in company with Captain Wm. T. Willis of the Core Bank Life Saving Station,

*VOL. XXII, No. 1, 1906, pp 17-19.

and Mr. R. C. Holton of Atlantic, the washing up of sand from the sea and the southward movement of the dunes having nearly filled them.

The Tertiary shell-rock was encountered in Core Sound between Core Bank and Cedar Island, and between Core Bank and the mainland. There is thus no longer any question as to the origin of Core Bank or of Currituck Bank, for they are both essentially parts of the mainland. Currituck Sound was formerly a river that flowed into the Albemarle or Caroline River before the present Albemarle Sound was formed by the drowning of that valley; and Core Sound was for the greater part of its length a southern tributary of the large river made up of the Pamlico and the Neuse, and passing to seaward through the present Ocracoke Inlet. The Albemarle River passed through the present fresh ponds just south of the Kill Devil Hills, and the margin of the continent was some three score miles eastward of its present position.

Then came the subsidence which drowned out the lower river valleys producing the estuaries and sounds already mentioned, and this subsidence may still be in progress in the region to the north of Cape Hatteras.

Since that subsidence, however, there has been an uplift of the land from Cape Hatteras southward, which, in all probability is still going on. As the dunes advance towards the sound side they depress by their weight the swamp muck in which the trees of that side grow, and these are left exposed on the seaward side when the dunes have passed. This compression of the muck, which is common from Hatteras Island northward, may easily be mistaken for subsidence of the land.

But on the land opposite Core Bank, successive strata of muck, filled with well-rounded wind-blown sands rise twenty feet above Core Sound at Atlantic. Kitchen middens, too, mark this line of elevated shore, the heaps being composed mainly of oyster shells with an occasional bit of broken

Indian pottery, and an occasional stone cleaver. Similar evidences of recent elevation have been observed by the writer at various points from Cape Hatteras to Cape Sable.

NOTE—This paper was presented, with lantern illustrations, before Section E, of the American Association for the Advancement of Science, New York, December 31st, 1906, and an abstract appears in *Science* N. S. vol. xxv, p. 297, Feb. 22, 1907.

NOTE ON ELECTRICAL AGEING OF FLOUR.

J. W. GORE.

The Alsop Process of Ageing flour was described in the Electrical World of December 8th, 1906, which is now in use in many mills in the United States and also in foreign countries.

The apparatus consists of a 500 volt Shunt Wound dynamo, with an induction coil in series with it, and an air pump.

The circuit is automatically broken at each stroke of the pump; the break is between two copper electrodes, and the resulting arc is drawn out until broken.

The air through which this flaming Electrical discharge passes is forced by the air pump through the flour as it comes from the mill.

A $1\frac{1}{2}$ kw dynamo is sufficient for a mill of some 30 to 40 barrels daily output.

It has been the practice of millers and warehouse men for a long time to age fresh flour by storage, thus fitting it better for bread and yielding a higher grade product. By Alsop's process these beneficial results are obtained in a few moments.

The conclusion is that the active elements in the atmosphere which improve the bread making qualities of the flour when stored, are plentifully produced by the flaming discharge of Electricity between Copper Electrodes.

INDUSTRIAL AND SCIENTIFIC ASPECTS OF THE PINE AND ITS PRODUCTS.*

BY CHAS. H. HERTY, PH.D.

Consideration of the annual production of volatile oils shows at once the great preponderance of spirits of turpentine over all others combined. Each quart of spirits of turpentine represents approximately one year's output of this product from one tree. At least nine-tenths of the world's supply of this substance comes from our Southern States, for the production of which not less than one hundred and twenty millions of trees are annually subjected to turpentineing. Two millions of acres of virgin timber are annually brought into operation to supply the place of exhausted timber. Millions of pines which have never been turpentineed are felled each year by the mills in Mississippi, Louisiana and Texas. Every winter the entire turpentine producing section is swept by ground fires which destroy most of the seedlings, and thus make impossible reproduction on any large scale. The annual revenue from the naval stores industry can be conservatively estimated under present prices at not less than forty millions of dollars. Surely such a situation justifies and demands systematic experimental work in the hope of conserving this valuable native resource.

EFFECT OF TURPENTINING ON LUMBER.

The pine has a two-fold commercial value, first, as timber, second, as a producer of the oil-resin, "crude turpentine."

*Reprinted from *The Chemical Engineer*, March, 1907.

For many years it was believed that timber which had been turpented, commonly called "bled timber," was inferior to "unbled" for construction purposes. A thorough investigation of this question in 1893 by the Division of Forestry of the U. S. Department of Agriculture showed the fallacy of this belief, and now no distinction is made. Indeed in France timber from trees which have been turpented is preferred for all purposes where strength and elasticity are demanded.

CRUDE TURPENTINE.

Previous to the last twelve years no systematic experiments had been carried out in this country on the production of crude turpentine. The records of the U. S. Patent Office as far back as 1869 show various inventions designed as substitutes for the "box," this being a deep hole cut in the base of the tree, having a capacity of about one quart and serving to collect the crude turpentine which flows from the scarified trunk above. None of these devices however gained permanent favor among turpentine operators. In 1894 W. W. Ashe, of the N. C. Geological Survey, began a comparative study of crude turpentine collected by the "box" system, uniformly practiced in this country, and by the "cup" or Hugues system, practiced in France. These experiments were planned with care, and although carried out on a small scale gave interesting results. They were discontinued after one year.

In the hope of accomplishing something toward the conservation of the pine forests of Georgia I began during the summer of 1901 field experiments on the production of crude turpentine by the pine. With an apparatus somewhat similar to that used in France, but essentially modified to suit our system of scarification or "chipping," various studies, both qualitative and quantitative, were made in the pine forests of the southern part of the State. Many of the specimens collected were afterwards examined in the chemical laboratory. The striking character of the results obtained aroused the interest of the U. S. Bureau of Forestry, and during the fol-

lowing winter I was led to accept a commission in the Bureau for the purpose of carrying out on a commercial scale the experiments already begun.

As introductory to the discussion of that work let me explain briefly the operations commonly in practice in the turpentine woods. During the winter the "boxes" are cut in the trees. In early spring the weekly scarification or "chipping" begins. It is necessary to renew this wound each week, as the flow of crude turpentine practically ceases after seven days. Chipping extends each year about eighteen inches up the tree, the depth of the cut being about one inch and the width, on an average tree, fourteen inches. When the boxes fill, usually every four or five weeks, the crude turpentine is removed to buckets, then to barrels and hauled to the still. During the year some of the product remains sticking to the exposed "face" of the tree. This is collected in the fall and distilled, although it has a much smaller percentage of spirits of turpentine than the "dip" from the boxes. Lastly a space around each tree is cleared of all combustible material as a protection against the annual ground fires.

The basis of my work was the conviction that the pine is not so much a store-house but rather a factory for the production of crude turpentine, and that timber which is not boxed should produce more than timber whose vitality is diminished by the cutting of the box. Comparative experiments were carried out in 1903 at Ocilla, Ga., on thirty thousand trees. In these experiments both the "box" and the "cup and gutter" systems were used under conditions as nearly identical as possible. The results showed an even greater difference in favor of the unboxed timber than was expected, while the qualitative results previously obtained by Ashe were confirmed. The immediate commercial introduction of the cup and gutter system was assured by the financial gain from the increased output, the improved quality of the rosin and the protection given to the trees against wind and fire.

For the production of crude turpentine it is necessary to

wound the tree. If the tree is girdled it dies. What then is the limit of wounding to which it is necessary to subject the tree in order to get the most profitable yield, and beyond which it is unsafe to go? It had been proved at Ocilla that the box was an unnecessary wound and that by its elimination the yield could be increased. The next step then was to make comparative tests bearing upon the extent of the wound given in "chipping." For the past two years such experiments have been conducted in Florida by the U. S. Forest Service, and by the courtesy of the Service I am enabled to tell you that results already obtained show that shallow chipping produces as much or eventually more crude turpentine than the customary deep chipping, while at least one year in three can be gained in the usual rate of ascent of the tree without diminishing the output. Still other experiments yielding most valuable results are in progress, all bearing upon more conservative wounding of the tree. None of these experiments are extreme, but all are rational modifications of present practices which will carry conviction when the details are published.

Of an entirely different character from the experiments just mentioned, but of great scientific and practical value, are the recent studies of Prof. A. Tschirch, of Switzerland, on resin secretion. By the use of the microscope and suitable stains he has proven that the seat of resin production is in a mucilaginous layer lining the inner walls of the resin ducts. In a later study, carried out upon a large number of trees, he has further demonstrated that while there are a limited number of "primary" resin ducts present in the untapped pine, by far the greater flow of resin proceeds from secondary ducts formed in the outer sap wood after the wounding of the tree. The resin from the "primary" ducts is a physiological product, that from the "secondary" a true pathological product.

While many chemical studies have been made of the products obtained by distillation of crude turpentine, only one detailed investigation is on record regarding the nature of the

oleo-resin secreted in the Longleaf pine. Tschirch and Koritzschoner have shown that this oleo-resin consists of

Palabienic Acid— $C_{13}H_{20}O_2$	5	per cent.
Palabietic Acid— $C_{27}H_{30}O_2$	6	" "
α and β —Palabietic Acid— $C_{16}H_{24}O_2$	56	" "
Spirits of Turpentine	20	" "
Paloresene	10	" "
Impurities, Bitter Principle and Water	3	" "

No study has been published of the oleo-resin from *Pinus Heterophylla*, or Cuban pine, which occurs so frequently in the Florida forests and from which therefore so large a proportion of the present supply of spirits of turpentine and rosin is prepared. Such an investigation has been begun in the laboratory of the University of North Carolina.

Many interesting new lines of investigation in this field suggest themselves if the chemist instead of waiting for specimens to reach the laboratory will study and note the changes at the tree. When the oleo-resin first appears it is a perfectly clear liquid. In the case of some pines it remains thus for weeks and then slow crystallization of the dissolved acids begins, with others the crystallization begins within a minute after the drop appears. Evidence already in hand points to the probability that the clear liquid issuing from the resin ducts is a supersaturated solution. To what is this condition of supersaturation to be ascribed? Again, the flow of resin is relatively rapid during the first forty-eight hours after wounding, then quickly diminishes and practically ceases after seven days. Is this cessation to be explained by the plant physiologist or by the chemist? Has the inner lining of the resin duct lost its power of production, or has the duct been closed by oxidation, or crystallization of the oleo-resin which it exudes? If chemical, can it be prevented by some simple means? A practical solution of this problem would be a great blessing to the turpentine operator in these days of scarcity of labor and would do more than anything

else for the preservation of our pine forests. Still again—what is the chemistry of “scrape” formation? Why the variation in the amount of scrape formed in pines of different species and even among those of the same species? These are a few of the many problems in this untouched field awaiting the skill and patience of the investigator.

DISTILLATION.

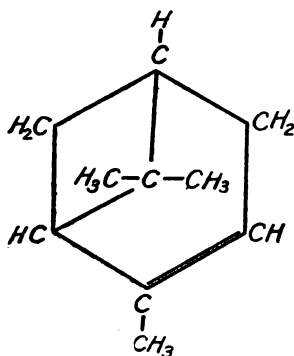
Crude turpentine is of very little commercial use. It must be separated by distillation into its constituents, spirits of turpentine and rosin. In this country distillation is carried out in large copper stills heated by direct fire. During distillation a current of warm water is let into the still. The steam produced by the water added during distillation materially lowers the temperature and lessens the time necessary for the complete removal of the spirits of turpentine. An interesting study of this subject from a physico-chemical standpoint has been made by Prof. Vezes, of Bordeaux. By distilling at this lower temperature the possibility of destructive distillation of the rosin is avoided. The vaporized spirits of turpentine and the steam are condensed in a water jacketed copper coil and collected in a suitable vessel where separation takes place owing to the difference in specific gravities and the mutual insolubility of the two liquids. On completion of the distillation the cap of the still is removed and the excess of water boiled off to prevent opaqueness in the rosin. The molten rosin is then run through an opening near the bottom of the still into strainers lined with cotton batting through which it filters into a vat. After partial cooling the rosin is dipped into barrels where it slowly solidifies.

During the summer of 1903 I had opportunity to study the systems of distillation practiced in France. Three types were found, first distillation by free flame and addition of water, as in this country, second by steam alone in steam jacketed stills, and third by a system of “mixed injection,” i. e. free

flame and addition of water together with steam injection. The cost of a plant for distillation by steam alone is far greater than that of the simple plants in this country. After careful study of these systems I am convinced that if a skillfull "stiller" is in charge, as good results are obtained here as with the best of the French steam stills, but the personal equation, which plays no role in the steam still, is of prime importance with us. Perhaps the best of these for our conditions would be that of mixed injection, for the extra cost of installation and operation is not great and the personal element of the "stiller" is entirely eliminated.

SPIRITS OF TURPENTINE.

The chief constituent of spirits of turpentine is pinene, $C_{10}H_{16}$. Many battles have been waged over the structural formula of this compound. At first it was classified among the open chain hydrocarbons but later was shown to be a ring compound. Of the many formulas proposed that of Wagner is most in accord with the reactions of the substance.



Some of the work upon American spirits of turpentine has been in vain, because investigators failed to take into account the facts that in our turpentine orchards more than one species of pine is turpented and that the crude turpentine from each is indiscriminately mixed when collected. Recognizing these

facts J. H. Long in 1893 secured specimens from identified individual trees, distilled the volatile oils from each and concluded that while American turpentine rotates the plane of polarized light to the right the variations in the amount of rotation in different specimens is due to admixture of the lævo-rotatory oil from Cuban pine with the dextro-rotatory oil from the Long leaf pine, and as the latter tree generally predominates the resultant oils are more or less dextro-rotatory. New light has been thrown upon this subject by an investigation carried on during the past year in the chemical laboratory of the University of North Carolina in collaboration with the U. S. Forest Service, by which the results of this study are to be published shortly. Through the courtesy of the Service I am enabled to refer to some of the results of special interest in this connection. During the past season, at regular intervals of four weeks, the crude turpentine has been collected separately from seven Longleaf and seven Cuban pines. A study of the oils distilled from these specimens has shown a marked variation in the rotation of polarized light. The variation exhibits itself not only in the oils from the two species of pines, but even among those from the same species. The Longleaf pines generally yielded dextro-rotatory oils. One, however, yielded a lævo-rotatory oil, while another scarcely affected the plane of polarization. The Cuban pines gave generally lævo-rotatory oils but through wide variations, one of them effecting only a very slight rotation. In the case of each tree, however, the rotation of its oil was found to be practically constant throughout the season.

The rapid rise in the price of spirits of turpentine during the past few years has led to frequent adulteration and the offering for sale of many substitutes. The producer, tempted by the great difference in price of spirits of turpentine and kerosene, has frequently mixed the two. The remedy was peculiar. Seeking to advance the price by producing less spirits of turpentine, the operators soon found that their successful effort to curtail had been fully off-set by the addition,

at many stills, of kerosene sufficient to keep the output at its former figures. The most prominent producers then led the fight for "pure spirits" laws and in the largest producing States effective legislation on this subject has been enacted. Similar laws have recently been passed in New York State.

Mineral oil constitutes the chief adulterant of spirits of turpentine. While such an addition may not materially lower the solvent power, it diminishes the oxygen carrying power directly in proportion to the amount present, since American petroleum is composed almost wholly of saturated hydrocarbons. So skillful has become the art of adulterating with petroleum products that detection by the ordinary physical tests can be evaded if the adulterant is not present in too great quantity. But by polymerization of the terpenes with concentrated sulphuric acid, Herzfeld's method, adulterations even as low as one to two per cent. can be detected with certainty. Especially is this true if after successive polymerizations the oils, distilled with steam, be examined with the refractometer, as recommended by McCandless.

No discussion of spirits of turpentine would be complete without embracing that form now legally designated as "wood spirits of turpentine." It is no new thing that a volatile oil, various heavy oils and charcoal can be obtained by destructive distillation of "fat lightwood." More than forty years ago extensive plants for such distillation were in operation in North Carolina. But the low price of spirits of turpentine made these financial ventures unsuccessful. A few plants continued operations on a small scale, but the matter dropped out of public notice for a long while. With the recent rise in price the subject was again agitated. By the aid of clever promotion, by the exhibition of actual results obtained, but from raw material above average richness, by frequent reference to latter-day success in saving and utilizing by-products and finally by that sweet vision of pestiferous stumps removed from the cotton rows, great enthusiasm was raised, and at one time unlimited capital was available for destructive dis-

tillation plants, provincially called "stump factories." Many were built, but it was soon found that the paint and varnish people did not want the product, as the quality was irregular and the odor bad. Then, too, the by-products so carefully saved found no market. Finally through faulty construction or careless management many of the plants burned. Consequently destructive distillation lost favor and plants were erected for the extraction from lightwood by steam of spirits of turpentine alone. This method gives an oil of good quality, and with increased experience a product is now manufactured which is practically the same as "gum spirits." But the yield from average raw material is rather low and if it be sought to increase the yield by elevation of temperature the quality is inferior.

I think I have stated the case fairly. We all hope that this industry will eventually be placed upon a good solid basis. Let me emphasize three points in connection with this subject:—

First.—Fewer promoters and more chemists would improve the situation.

Second.—Investors must not expect to realize the enormous profits claimed by some of the over-enthusiastic, but the business is capable of yielding fair dividends if the plants are properly located and carefully managed.

Third.—In spite of the preference now shown for steam extraction, the future of this industry lies in destructive distillation, but not as at present practiced. The difficulty of securing profitably a permanent supply of raw material will lead to the establishment of numbers of cheap stills. Such stills require no expert labor and can be easily moved from time to time to fresh portions of the territory for raw material. The crude product from these small stills will be shipped to central refineries where suitable apparatus will be found operated under the direction of chemists.

ROSIN.

What is rosin and of what chemical compounds is it

composed? This question has interested chemists for many years. The literature of the subject is very extensive and the views held at various times were and even now are widely different. By Maly and Flückiger rosin was considered the anhydride of abietic acid. Henriques contended for the presence of lactonic acids, Benedict for free acids and ethereal salts, Fahrion for sylvic acid, while Tschirch has recently separated from American rosin three isomeric acids α , β and γ abietic acids, and considers that all other workers in this field have been dealing with impure products. The controversy on this subject between Tschirch and Fahrion is not yet ended. Tschirch can not decide between $C_{20}H_{30}O_2$ and $C_{20}H_{28}O_2$ as the correct formula for abietic acid. Nor has it been determined with any certainty whether the oxygen atoms of this acid are present in the form of hydroxyl or carboxyl groups. It is possible that some of these differences may be due to the fact that many of the specimens used for investigations are so called "American Rosins," without taking into account the fact that much of this rosin is derived from at least two different species of pines, *Pinus Palustris* and *Pinus Heterophylla*.

Rosin varies in color from a pale yellow to a very deep red, the price of the rosin decreasing with increasing color. In France the better grades of rosin are placed in shallow trays and exposed for three or four months to the bleaching action of sunlight. Almost colorless grades are thereby obtained. This practice is carried on by one firm in this country. But sun-bleaching is not effective with the darker rosins. The great difference in price between the low and high grades has led to many efforts to devise chemical methods for bleaching rosin. A number of patents have been issued on the subject, but so far as I know none of these have proved commercially profitable. Here is a live problem for the chemist, the correct solution of which is certain to bring rich returns.

For many years the commercial demand for rosin was very

limited. Indeed at one time the price dropped so low that it was frequently the custom in North Carolina to distill the oil from the crude turpentine and turn the rosin into the creeks and swamps. In these latter days of higher prices the rosin from these dumping grounds has been dug up, melted, strained and shipped to market. The cause of this increase in price is not difficult to discover. It is the manufacture of rosin oil. Of the total amount of rosin produced about 10 per cent. is used for sizing, varnishes and other minor matters, 35 per cent., approximately, for soap making, while not less than 55 per cent. is subjected to destructive distillation whereby rosin spirits, various rosin oils, brewers pitch, etc., are obtained. As a substitute for or adulterant in linseed oil, as lubricants, in printer's ink and in many other ways rosin oils are finding wider and wider application. This industry thrives chiefly in Germany, to quite a large extent in England and Scotland, and a much more limited extent in France, where a high tariff prevents the importation of American rosin. In this country there are about three rosin oil distilleries, operated somewhat in the same manner as the European plants. Why should not this industry thrive in our Southern States? It would seem that the same logic which led to the recent movement to erect cotton mills near the fields of cotton would apply in this case also. We have a great advantage over the foreign manufacturer if we will only make use of it. When the German or English rosin oil manufacturer gets the rosin thoroughly melted in his still he is just at the point where we were at the moment the molten rosin was turned out of our turpentine still into the vat. Meanwhile what has happened? The heat stored up in the molten rosin has gone to waste, there has been added the labor of dipping it from the vat into the barrels, the cost of inspection, broker's commissions, transportation costs, labor in getting the rosin from the barrels and breaking it into lumps of suitable size for the still, and finally the cost of fuel for again melting the rosin, and why? All in order to get it

back again into the condition in which we once had it. Many industries have been developed on a much narrower basis of saving than that just indicated. Adjacent to each of our turpentine stills there should be found one or more for rosin oil, placed on a lower level, so that the molten rosin could be run directly from the one to the other and destructive distillation of the rosin begun. The stills for rosin oil being made of iron are not expensive and the skill required for distilling is far less than in the distillation of crude turpentine. Again, but little labor would be required, nor would it be necessary to find markets or uses for the products: these already exist and are constantly increasing. With such manifest advantage we should be able to locate the whole of this industry in our midst.

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**PROCEEDINGS OF THE NORTH CAROLINA ACADEMY OF SCIENCE, SIXTH ANNUAL MEETING,
HELD AT CHAPEL HILL, MAY
17TH AND 18TH, 1907.**

The executive committee met Friday, May 17th at 1 p. m., the following members being present: Collier Cobb, W. C. Coker, John F. Lanneau, and F. L. Stevens.

The following names were proposed for membership to the Academy and were elected to membership by the executive committee: Dr. C. H. Herty, Chapel Hill; Dr. J. H. Pratt, Chapel Hill; Dr. A. S. Wheeler, Chapel Hill; Dr. J. E. Mills, Chapel Hill; Dr. R. O. E. Davis, Chapel Hill; N. C. Curtis, Chapel Hill; J. G. Hall, West Raleigh; H. W. Smith; W. A. Withers, West Raleigh; Dr. G. A. Roberts, West Raleigh; F. P. Drane, Chapel Hill; R. T. Allen, U. S. Geological Survey; J. E. Pogue, Jr., Chapel Hill; Miss Daisy B. Allen, Raleigh; Louis W. Gaines, Wake Forest; W. N. Hutt, Raleigh; J. J. Wolfe, Durham; M. H. Stacy, Chapel Hill; Clifton D. Howe, Biltmore; C. W. MacNider, Raleigh; Will L. Brewer, Greensboro.

At 3 p. m. Friday, the 17th, the Academy was called to

Printed June 17.

order by its President, Professor Collier Cobb, and an address of welcome was extended to the Academy by President Francis P. Venable, of the University of North Carolina. A response to the address was made by the retiring President, John F. Lanneau, of the Academy of Science. The remainder of the afternoon session was devoted to the presentation of papers.

At 9 p. m. the Academy met in Gerrard Hall, and the presidential address, "The Garden, Field, and Forest of the Nation," was delivered by President Cobb. Following this address a reception was extended the visiting members in the Y. M. C. A. building.

Saturday, May 18, at 9 a. m., the Academy convened for a business meeting. The minutes of the last meeting were read and approved, and the names of the new members, as elected by the executive committee, were read and formal vote of election to membership was made.

The nominating committee, previously appointed, presented for election the following names: President, T. Gilbert Pearson; Vice-President, W. C. Coker; Secretary, F. L. Stevens; members of the executive committee, Franklin Sherman, Jr., J. J. Wolfe, and John F. Lanneau. It was moved by F. L. Stevens that the name of E. W. Gudger be substituted for that of F. L. Stevens for Secretary. The amendment was carried. These nominees were then elected to office for the ensuing year. The report of the Treasurer, showing a balance of \$122.53, was received. Raymond Binford and Franklin Sherman, Jr., were appointed as auditors. It was moved and carried that the executive committee be requested to hold the meeting next year two weeks earlier than that of this year.

Following the business meeting was held a meeting for the presentation of papers.

The following papers were presented:

1. The Sparsity of the Stars, the Measureless Remoteness of

each Star from All Others, John F. Lanneau, Wake Forest College.

The paper will appear in full in *Popular Astronomy*.

2. The Foundations of Geometry, Archibald Henderson, of the University of North Carolina, published in The Journal of the Elisha Mitchell Society, May, 1907.
3. Some New Sources of Light, C. W. Edwards, Trinity College. Read by title.
4. Some Interesting Grasshoppers (and Their Relatives) of North Carolina, Franklin Sherman, Jr., State Entomologist.
5. Osteogenesis Imperfecta (with a report of a case), Lewis M. Gaines, of Wake Forest College. Read by title.
6. Notes on the Cultivation of Algae for Class Use, F. L. Stevens, of the North Carolina College of Agriculture and Mechanic Arts.

Suggestions were given for the isolation and cultivation of algae upon solid medium, consisting of 75 per cent, agar made up with Knopf's solution. This medium solidifying at lower than 34 degrees, can be safely used in plating out algae. Cultures of several forms were exhibited.

7. Fusion of Sponge Larvae with formation of composite sponges, H. V. Wilson, of the University of North Carolina.

The ciliated larvae of silicious sponges (*Stylotella*) may be made to fuse, thus giving rise to composite sponges. To accomplish this result it is only necessary to bring the larvae in close contact at the time when the ciliary action is no longer locomotary and fixation is about to occur. The composite masses representing (in the actual experiments) from two to six larvae complete the metamorphosis.

8. Wind-polished pebbles, and Palaeolithic Man, Collier Cobb, of the University of North Carolina.

The close similarity between pebbles faceted and polished by the sand-blast and the implements of early man was indicated, and the errors which might result from superficial observation were pointed out.

9. Notes on the Zoology of Lake Ellis, C. S. Brimley, Raleigh, N. C.

The paper discusses the occurrence of various insects and reptiles taken by the writer and others in the vicinity of Lake Ellis, Craven County, N. C., during June, 1905, and May, 1906. The rare salamander, *Stereochilus marginatus*, which had not been taken for many years, was found to be common, and several specimens of the frog, *Rana virgatipes*, were taken. Nine alligators were secured on the two trips by the author's companion, and several rare snakes. Five species of dragon fly, new to North Carolina, were secured, and (in June, 1905,) numerous specimens of the yellow fly (*Diachlorus ferrugatus*). Notes on other members of the Tabanidae are also given.

10. Single Phase Railway Work, J. E. Latta, of the University of North Carolina.
11. The Relation of the Cattle-tick to Southern Agriculture, Dr. Tait Butler, State Veterinarian, Raleigh, N. C.
12. The Design of High Masonry Dams, William Cain, of the University of North Carolina.

The method of finding the resultant of the water-pressure and the weight of masonry pertaining to any horizontal joint of a dam is given; also the decomposition of the vertical component of this resultant along the joint according to the usual hypothesis. The hypothesis of the conservation of plane sections, in the case of a battered wall, is then criticised and the resulting vertical unit pressure at a face of the

wall, shown to be too high and therefore on the side of safety. But since the pressure near a face, acts necessarily parallel to that face, the vertical unit pressure just computed, is not the whole pressure.

The difficulty of computing exactly this whole pressure is next entered into and an upper limit found by an approximate method which again gives an excess pressure.

Rankine's suggestion, to use the ordinary formula for vertical unit pressure, but specify higher limiting unit pressures for the up-stream face than for the down stream face is adopted provisionally.

The claim is made that, in addition to the three universally imposed conditions, no tension, safe unit pressures and no possible sliding at any horizontal joint—a fourth condition must be imposed, viz., that the factors of safety against overturning and sliding shall increase gradually from the base upwards to allow for the proportionately greater influence, on the upper joints of wind and wave action, floating ice or other bodies, and especially of the great forces caused by the expansion of thick ice under an increase of temperature and by earthquakes.

It was found that this could easily be done by taking the well-known theoretical triangular type of cross-section of dam and making some additions at the top sufficient for a roadway.

A preliminary design is given for a dam 258 feet high, with factors of safety and unit pressures marked on the drawing, satisfying all four conditions. The area of cross-section and height being the same as for the celebrated Quaker bridge design, a comparison was instituted, unfavorable to the latter, in that its factors of safety are too small, particularly in the upper portions, where by the proposed fourth condition they should be largest.

This criticism owes its significance to the fact that the new Croton Dam of New York, 224 feet high to water surface and finished February 1st, 1906, at a cost of over \$7,500,000, has

a profile for 224 feet in depth, exactly the same as the Quaker bridge design for the same depth.

Engineering News for June 30, 1888, January 12, 1893, and May 9, 1907, is referred to for the destructive action of ice on ponds, lakes, and rivers, due to the expansion from an increase of temperature during the day. At night, contraction causes cracks to form, often several inches wide, which are filled up with new ice and thus the effect, from day to day is cumulative and very destructive as far north as Canada and in the Northern States. As yet, the action of ice on high dams has not received much attention.

For earthquake action on houses, Milne is referred to; also a personal experience of the author in Charleston, S. C., is recited. It was pointed out, however, that dams being built into the sides of the valley at their ends, were not so free to move at their tops as houses.

A brief description and analysis of the failure of the Habra dam concludes the paper.

13. Three Little Known Species of North Carolina Fungi, J. G. Hall, of the North Carolina Experiment Station.
14. A New Form of *Achlya*, W. C. Coker, of the University of North Carolina.

During the fall of 1906 an *Achlya* was found at Chapel Hill, N. C., which agrees with *Achlya racemosa*, var. *stelligera* Cornu, in many respects, but different from it in having the autheridium cut off immediately below the oogonium, and the fertilizing tube arising from the division wall and entering the oogonium from below, as in *Saprolegnia hypogyna* Pringsheim. Such an origin for the fertilizing tube is new for the genus *Achlya*, and is not known elsewhere except in *Saprolegnia hypogyna*.

15. Notes upon the Preparation of the Silicate Medium for the Cultivation of Bacteria, J. C. Temple, N. C. Agricultural Experiment Station.

Directions were given for the preparation of this medium obviating the necessity of dializing, and making it possible to prepare this medium with greater certainty and greater accuracy. The use of the medium prepared in this way for the culture of various organisms was illustrated by colonies of various bacteria growing in a thriving condition upon the medium.

16. Breeding Colonies of Birds (Illustrated with Eggs and Stereopticon views), T. Gilbert Pearson, of Greensboro.
17. The Efficiency of Soil Inoculation in the Production of Root Tubercles, F. L. Stevens, of the North Carolina Agricultural Experiment Station.

Data was given concerning the inoculation of soils with liquid cultures obtained from the Department of Agriculture, Washington, D. C. From many tests conducted in various ways there was no evidence whatever that inoculation with these cultures was efficient in the production of tubercles upon the legumes. The cultures employed were issued in liquid condition in hermetically sealed test tubes, and were obtained directly from the Bureau of Plant Industry, Washington, D. C.

18. The Opportunities for Study and Research at the Beaufort Laboratory, H. V. Wilson, of the University of North Carolina.
19. Does Blood Tell? Heredity According to the Experience of the Children's Home Society, William B. Streeter, of Greensboro, N. C.
20. Geology of the Cape Fear River, Joseph E. Pogue, Jr., of the University of North Carolina.
21. The Relation of Sporangium of *Lygodium* to the Evolution of the Polypodiaceae, Raymond Binford, of Guilford College.

22. The Condensation of Alipatic Aldehydes with Aromatic Amines, Alvin S. Wheeler, of the North Carolina University.

The following reaction takes place without any dehydrating agent: $RCHO + 2RNH_2 = RCH(RNH_2)_2 + H_2O$. In some cases at low temperatures the addition product is obtained. Condensation products of Chloral with the three nitranilines, p-bromaniline, o-toluidine, anthranilic acid, and o-anisidine were prepared. By-products, as yet unidentified, were obtained with o-toluidine and with anthranilic acid. The condensation products are readily broken down by Hydrochloric acid and by acetic anhydride. When suspended or dissolved in the glacial acetic acid they react with extreme smoothness with bromine, forming beautifully crystalline compounds which are much more stable than the condensation products.

23. Chapel Hill Ferns, by W. C. Coker, of the University of North Carolina.

A collection of the living ferns and fern allies native to Chapel Hill, N. C., was made and exhibited in pots. Twenty species were represented, including all the known Pteridophytes of the neighborhood, except *Botrychium ternatum* and its variety, *dissectum*, which had not yet appeared above ground.

24. Notes on Turtles of Genus *Pseudemys*, C. S. Brimley, of Raleigh, N. C.
25. Electricity in Heavy Traction (Illustrated by lantern slides), J. E. Latta, of the University of North Carolina.
26. The Optical Rotation of Volatile Oil, C. H. Herty and G. A. Johnson, of the University of North Carolina.
27. Children's Home Society Methods, William B. Streeter, of Greensboro'.

28. Gametophytes of *Botrychium Virginianum*, Raymond Binford, of Guilford College.

They were found in moist oak woods under the leaves. Some were almost on the surface of the soil while others were imbedded one to two inches in the soil. They seem to have gotten down by means of worm holes or cracks made by roots of trees. Sizes ranging from 2 m. m. to 10 m. m. were shown. Specimens of these plants were exhibited before the Academy.

A motion of appreciation of the courtesies extended to the Academy by the members at Chapel Hill and ladies of Chapel Hill was unanimously carried.

At 1:30 o'clock Saturday the Academy adjourned.

F. L. STEVENS, Secretary.

THE GARDEN, FIELD, AND FOREST OF THE NATION.

BY COLLIER COBB.

(Address as President of the North Carolina Academy of Science.)

It has been the boast of more than one of our politicians that North Carolina could well be independent of the rest of the world, for we might enclose the State with a high wall and get along just as well, since we produce within our borders everything that we need. This boast was based on the fact that North Carolina puts something in every column of the blanks sent out by the Agricultural Department at Washington, that she produces a little of everything; but the inference drawn from this fact is far from being true. Not a single county in the State produces food-stuff sufficient to sustain its population. As our towns and cities have grown, the relative food production has diminished, and in most of our counties this diminution in the amount of food produced has been not only relative but absolute.

For the last score of years the population of our towns and villages has increased as families have gone from the farms to the factories, often to live off the labor of the children, or from the rural districts to the city in order to give the children better schooling. The increase of our population from outside sources, too, has helped to swell the urban population. But farm lands are not increasing, the acres planted with food stuffs have steadily diminished in number, and under our old system of cultivation there has been a steady diminution in the value of the returns per acre. Even

Orange County, which may be reckoned a rural district, does not begin to make food enough to maintain its inhabitants through the year, and the inhabitants of our adjoining county of Durham would starve in less than a fortnight if they had to depend on the food product of the county for support. When some of us in this hall came to college the village of Durham could claim no other distinction than that of being the railway station from which students drove to Chapel Hill. Today it is a city of more than 20,000 inhabitants, drawing its population from all parts of the world, and dependent upon distant fields for its support. And not one of our large cities, Wilmington, Charlotte, Asheville, Greensboro, or Raleigh, could depend on its own county, or even upon the surplus of a score of adjoining counties, for its food.

Notwithstanding the several years of unprecedented crops that we have had, amounting almost to seven years of plenty, we are practically face to face with a famine. The wheat lands of our own Northwest have been practically exhausted of their lime, as an acre of wheat will use up ten pounds of lime in coming to maturity; and this loss, added to the damage done the soil by the poisons excreted by the roots of the wheat, has caused our farmers of the great plains to seek new fields in the Canadian West. Already the natural pasturage of our semi-arid regions has been practically exhausted, and neither cattle-raising nor sheep-raising is profitable, where within two decades vast fortunes have been made in these industries. Those of you who paid your month's butcher's bills on the first of May were doubtless led by their unusual size to investigate causes, and learned that for the first time in the history of the Chicago and Kansas City packing houses they have not been able to fill their cold storage. The demand of the country for fresh meat has consumed the entire output of these houses during their busy season. And this state of things has come about after three years of abundant crops, during which time the packing

houses have paid their own prices for meat. Now let a drought come and there is absolutely no escape from a meat famine.

But what are we going to do about it? What is the solution of the problem? We are all familiar with the fact that in our older States of the South the annual product per acre has greatly decreased, owing to the rapid loss of soil fertility, and that even our moderate production is maintained only at increased cost; and also, that the comparatively new States like Texas, as well, show a rapid deterioration of land and loss of fertility. And it may be pointed out that our farmer is of all men most miserable; neglected and looked down upon; slave to the credit system; servant where he should be master; poor and becoming poorer; the prey of sharpers; the disconsolate follower of a calling which he has inherited with his deteriorating acres, clinging to the past, knowing no higher law than chance, planting, rearing, and gathering his crop under the leadership of luck, each succeeding year seeing his granary heaped fuller of disappointments, leaving him poor in purse and lean in hope. None of us can deny that this is a true picture of the average farmer of our State as we have known him from our youth up. The politician who has flattered him biennially that his calling, seen in its true perspective, is outranked by no other in power, scope, or service to mankind, has gone his way and made laws directly opposed to all the farmer's interests.

Still, what are we going to do about it? How are we to escape famine if our present source of supply should be exhausted? What is the solution of the problem? Increase the output from the soil that we have by the application of science—"that sensible science of our day which has for its ultimate aim not merely discovery but application; which is not so delighted by the formulating of a new law as it is overjoyed at the lifting of a burden;" science, in which laboratory investigation goes hand in hand with field experimentation, the science of our present time, which is applied

common sense, combining laboratory practice with business-like methods. Such science our United States Department of Agriculture is engaged in and encouraging; so also the various State agricultural experiment stations and most of the agricultural colleges, corn breeders' associations, truck growers' associations, sugar producers, tobacco growers, private investigators like Luther Burbank, all laboring to lift the burden from the agriculturist, and make him indeed what the politician has been flattering him that he is. Greater progress has been made in all departments of life dependent upon the soil in the last score of years than in the previous two score centuries.

The most important of all this service of science to the farmer has been the study of the soil, the fundamental factor in all the varied lines of life that branch out from agriculture. How to save it, how to nourish it, how to restore it to life when dead, what it is composed of, how it is formed, how to interpret it so that any man may understand it—these have been, and still are among the great problems before us. Their solution is being worked out and already that work has revolutionized agriculture within our own State and is slowly changing conditions for the better in the entire South.

Tobacco is grown in eastern North Carolina today because a soil investigator found out that the marls just beneath the soil there contained in available form the lime that the tobacco plants require for their growth, and of course all the other essential minerals are there. Hitherto tobaccos had been grown on limestone soils, or on soils derived from igneous and metamorphic rocks rich in lime-soda feldspars.

In a similar manner it was discovered that the sands of the sand-hills regions of the Carolinas contain both lime and potash in available form, whereas similar sandy soils of Western Europe are practically devoid of these necessary plant foods, but this soil is particularly adapted to the growth of the vine, and in consequence an important grape industry has grown up in our sand-hills district.

Similarly it was found out that certain incoherent white quartz sand in Florida was valuable pine-apple soil, notwithstanding it was over 99.5 pure quartz, because it possessed certain properties that the bacteriologist discovered.

Investigation showed that the soil of the Connecticut Valley, which produced only low grade tobaccos, sneered at as Connecticut cabbage leaf, was essentially the same as that which produced the Sumatra tobacco. But it was necessary to change the climatic conditions, and this was done by the use of cheese-cloth, increasing the humidity and raising the mean temperature ten degrees Fahr. Somewhat similar experiments have been tried in Darlington District, South Carolina, the result, so far as the production of Sumatra wrappers was concerned, being entirely satisfactory. And such investigations and experiments have been carried on all the way from Connecticut to Alabama and Texas with the result of greatly improving the product and greatly increasing the output, producing in the Southern States the cigar tobaccos of all lands.

This matter of the investigation of soils is by no means new, though its methods and their application to agriculture are matters of little more than a decade. Such investigations were begun by Liebig at Giessen more than half a century ago. He and his assistants made countless analyses of the ashes of plants. These showed the presence of different minerals in every species, that each species requires from the ground the same class of salts, and hence that it must sooner or later exhaust the supply of these salts in a given plot, and render it unfit for the growth of the species in question unless fresh supplies are provided.

"Liebig attempted to give the necessary supplies in the form of 'Mineral Manure', and soon set to work to study practically the effect of mineral manures on a large scale. In the year 1845, previous experiments in a garden having proved unsatisfactory, he purchased from the town of Giessen about ten acres of barren land—a sand pit, as he says, which

surpassed all the land in the neighborhood in its barrenness for ordinary cultivated crops; in the year this land hardly grew so much fodder as would have sufficed for a single sheep. It consisted partly of sand, partly of coarse quartz and pebbles, with strata of sand and some loam.

"Some of the soil was first tested by sowing it with seeds in pots after enrichment with some single mineral manure, with the result that not one of the plants got beyond flowering; this showed that the soil was bad enough for his purpose of testing the value of minerals as manure.

"A number of mineral manures were then prepared for him according to prescriptions based on his analyses, and these were spread over the land; next he sowed on different subdivisions of it wheat, rye, barley, clover, potatoes, turnips, maize. In some cases he added sawdust to the manure, and in one case he used stable manure; otherwise no ammoniacal manure and no mineral matter was employed, except that to one plot he applied some forest soil and to another a mixture of forest soil and mineral manure. Even in the first year he had a harvest; the best results were given by those plots in which mineral manures were mixed with forest soil or stable manure. This, as he says, enabled him to correct his earlier ideas of the functions of humus, which by its decay renders an extra supply of carbonic acid gas to the plants that is especially valuable at the early stages. Gradually, without any other supply of manure except mineral manure, the land so improved in productiveness that in the fourth year his crops excited the wonder of all who had known the original state of it.

"In 1849 this little farm was purchased by his gardener, who was then able to farm it with profit, raising some cattle on it yearly and getting such satisfactory crops of corn that in 1853 a neighboring farmer wrote: 'With us the wheat crops are very poor, but on the height (Liebig's plot) they have harvested three fuder of rye twelve simmer, while I from three fuder of the best rye, have only got five simmer.

If you were to see it, you would be 'astonished; it is truly wonderful.' "

From his experiments with this land Liebig was led to form the opinion that it was possible, by giving the soil proper physical quality and composition, to bring about a state of things in which sufficient ammonia to maintain its fertility can be collected or condensed from the air. He recognized not only that certain elements were necessary in a fertile soil, but more—and what certain soil chemists have been slow to recognize—that these elements must occur in certain combinations as minerals to be available as plant-food. He found, too, that certain earths and other substances might be added to soils, which would withdraw to some extent soluble salts from their solutions, removing from the soil substances injurious to plant life. Liebig was greatly interested in the experiments made in England by Sir Thomas Way on the absorptive power of soils, and was the first to recognize the true value of these experiments to agriculture.

Thus it was that a chemist sixty years ago recognized that the study of soils was as much the province of the geologist, the mineralogist, and the physicist, as of the chemist; and the work with which he is credited in Denmark shows that he also regarded it as within the province of the botanist. So greatly did he value the structural features and mineral composition of a soil as indicators of its fertility, that he said: "In matters of this kind the farmer must pursue his own course.....he must not put the least faith in the assertion of any foolish chemist who wants to prove to him analytically that his field contains an inexhaustible store of this or that nutritive substance."

In other words, Liebig saw that it is not so much the chemical elements in a soil as their mineral combination which determines their available plant food, and the geologists have found that very different rocks may be made from the same molten magma under different conditions of cooling. And it was Liebig who pointed out to the farmers that they

might change the fertility of their soil by changing its texture. In examining into the improved conditions of agriculture in the dune districts of the Jutland Peninsula a number of years ago, I found that the farmers of that country attributed their prosperity wholly to the suggestions made to their fathers and grandfathers by Liebig who went to Denmark to study moving sands; but I have not been able to find that he ever published anything on the subject.

But the dream of Liebig is being realized, and the study of soils is enlisting the closest attention of the chemist, the geologist, the mineralogist, the bacteriologist, the botanist,—a relatively small but powerful coterie of men who are the investigators and interpreters of modern agriculture. The chemist has found the essential plant foods, the geologist has noted the natural distribution of vegetation with relation to rocks both as to composition and structure, the mineralogist and geologist have studied the rock-making minerals in relation to their available plant-foods, the bacteriologist has shown us that certain living organisms in the soil are of enormous importance to every man who raises food for man and beast, the botanist has busied himself with breeding certain plants adapted to certain soils. “Knowledge is now no more a fountain sealed.” The farmer of to-day may, nay he must, come up to his calling “as fully equipped for service as the lawyer, the editor, the doctor, the captain of industry; for the curious fact has developed that the calling in which the unlettered and untrained man was once supposed to have as good a chance as the educated one, is now the calling in which wide and varied knowledge is almost as imperative as in almost any other known among men.”

Of the more than seventy elements that make up the crust of the earth only about a dozen are essential to successful agriculture and practically all soils contain these in one form or another. Only four of the twelve—nitrogen, phosphorus, potassium, and calcium—are liable to be lacking in

any given soil. But when any one of these four is wanting dire results follow.

The results that may be obtained, even where all these elements are present in proper proportion, depend upon the size of the soil particles, upon the number of grains of soil in the little measure of a gram; for the freedom with which the film of soil moisture moves over the soil grains determines the amount of plant food taken out of the soil. If the farmer is a raiser of truck for the early market, the soil for his lettuce, peas, beans, onions and radishes must be of a certain well-defined structure—it must have at least one billion, nine hundred and fifty millions of particles in a gram, in less than a thimbleful of earth. If he is going in for ordinary summer and autumn vegetables, corn and cabbage and potatoes, then there must be at least two billion additional particles in each gram of soil. If he is a wheat planter he must be sure that there are not less than ten billion, two hundred millions of particles in his little thimbleful of soil; while for wheat and grass land combined the soil must be in finer particles still.

While it has been known for at least two centuries that bacteria exist in the soil, it is only recently that they have been studied with any degree of satisfaction. They exist everywhere in earth and air and sea. They were believed at one time to have animal life, but they are now almost universally accepted as low forms of vegetable life. Over a thousand different kinds are now known, and the list is being steadily added to as knowledge of them increases. They increase by dividing themselves in two, and this they do at a marvelous rate of progression. One of them, according to a bacteriologist who has studied it closely, would, if left to itself, produce seventeen million descendants in twenty-four hours. Another scientist calculates that another particularly rapid multiplier could produce, if it had plenty of food, four thousand seven hundred and seventy-two billion progeny in a single day. They differ from plants which we see growing

about us in that they have no chlorophyl—the material which gives the green color to the plants.

In a Kansas soil it was found that there were as many as one billion, six hundred and eighteen million, six hundred and eighty-one thousand, eight hundred and ten bacteria in a single gram or small thimbleful from a field under examination, while another field nearby had only a few over a million. As air is necessary for their existence, they rapidly decline in numbers as you go down in the soil to a point where none is ever found.

Many different families of these bacteria live in the earth, making their homes in the soil. They help to decompose it, thus transforming it into food. They draw vast stores of food supplies from the air. At every point they act as agents in advancing the interest of man.

Four-fifths of the air we breathe is one of the most valuable plant foods, nitrogen. Some of this nitrogen is available in one form and some in another, but it must all be put into such form that it may pass into the system of the plant and be utilized in the building up of stalk and leaf and ripened seed.

In portions of North Carolina I have seen a field worn out by injudicious cropping, the plants struggling to grow in a depleted soil into what would be at best but a lean and starved maturity. In an immediately adjoining field, with a soil of precisely the same character, with no advantage in point of moisture, heat, or sunshine, with precisely the same kind of seed planted as in the first case, were tall, strong, and thrifty plants, neighbors to the thin, yellow, beggarly ones of the first field.

The only difference between the two was that when the seed were planted there was sprinkled in the rows of one field some plain simple dirt brought from another State, and the field that had this dirt sprinkled in its rows was the field with the strong and vigorous plants. What wrought the wonderful change was a colony of nitrifying bacteria, living,

moving things, that helped the crops to get their nitrogen from the atmosphere. Long ago it was discovered that certain plants, as the beans, clovers, peas, vetch, alfalfa, and the like, form upon their roots little bunches of tubercles, as they are called. When science sought out the meaning of these tubercles, why they formed on these particular plants, what purpose they served, it was seen that they were not abnormal, but necessary, and that plants that had them were more thrifty than those that had them not. It was discovered that their task was to take nitrogen from the air and transform it into nitrogen suitable to be taken up by the plant.

Having learned, then, the soil conditions necessary for plant growth, the next thing is to apply them.

Residual soils, those found upon the rocks from which they are derived, have certain definite characters determined by the characters of the rocks beneath, and they are not apt to deteriorate, since their source of food-supply is immediately at hand, unless the fine particles are carried away by erosion faster than the rock beneath can rot into soil. Transported soils, on the other hand, are very readily exhausted, since they are far removed from the parent rock, and they need to have their supply of plant-food constantly replenished by the use of fertilizers. One way of keeping up the fertility of the soil is by rotation of crops requiring different plant-foods.

The best way to farm is to plant in each field the crop to which the soil of that field is by nature best adapted.

But we often desire, or actually need, crops to which the soil of a given district is ill-adapted. Since we cannot change the soil materially, the difficulty is met by breeding plants to suit the soil, and what has been accomplished in this direction is little short of miraculous.

The wasting of soils where serials are grown, and the gradual reduction, year by year, in the yield of these crops, has led more than one thoughtful student of human condi-

tions to predict a time, and that not very far distant, when there will not be bread enough to go around.

While enough has been done in the restoration of worn out soils to show that the time is farther away than was at first feared, much more has been done in the breeding of new varieties of wheat and corn to take the place of the old and unsatisfactory ones. New wheats have been created not only showing larger yields and as great nutrition in experimental plots, but in the thousand-acre farm of the advanced American Agriculturist as well. More than this, wheats have been bred to fit a climate, redeeming vast areas of abandoned land supposed to be wholly unfit for wheat production.

New corns have been created, far richer in food values, far larger in yield, than the best known types of the past. More than this, corns have been created at the command of man for any one of a series of specific purposes—to be rich in one element and lean in another, to be food for man or food for beast. They are, in a word, as much the creation of man as the beautiful vase in the hands of the potter.

The experiment station of the University of Tennessee determined to breed a wheat that should fit the soil and climate of that State, where no wheat would grow and produce good results. When the experiments were begun, eight bushels to the acre was a fair average yield. After several years of testing, breeding, and selection, they have produced a wheat that has produced as high as forty-eight and one-half bushels per acre on the same land, while maintaining an average of over thirty-seven bushels for a period of four or five years. And we in North Carolina have reaped the benefits of this and similar experiments elsewhere in the extension of wheat producing area to the poorer lands of the eastern part of the State.

When we consider corn, the greatest cereal in point of value of annual production in the United States, the results achieved are even more satisfactory. The object sought in breeding new corns was not only to produce corn with a heavier yield,

but to change the character of the corn itself. Corn for human food should be rich in one element. Corn for manufacturing into any of the various products which are now made from it should be rich in certain other elements.

So the corn kernel was studied in order to find out precisely what it was made of, that by selective breeding this might be changed. By taking kernels from a series of ears known to be rich in one particular element, and breeding from these ears year in and year out, carefully selecting for future seed only the richest and best kernels and only those approaching the ideal established, little by little, with infinite pains and patience, new corns have been built up having the desired character and composition.

A manufacturer desires corn for the production of oil, now one of the most valuable products of the corn plant. It is in large demand among the olive-oil manufacturers of Europe. The oil comes from the fat in the tiny germ of the corn, and the larger the germ the greater the supply of oil. Corn-oil is in demand for many other purposes, and it appears to be but at the beginning of its commercial life. Hopkins in Illinois has succeeded in producing a corn relatively much richer in oil than any that has preceded it, one having 6.96 per cent. oil while the corn with which he started only six years before contained only 4.7 per cent. of oil. To some manufacturers the fat of the germ is not essential, so, to accommodate these, he reversed the process and bred a corn low in fat or oil, reaching 2.99 per cent.

The element of the corn which is most valuable for strengthening food, which is the muscle-building material of all food, has also been increased at will, and where it could make way for some other element suitable for some other purpose, it has been decreased. All this has been accomplished by selective breeding. Corn has been produced having 16.11 protein, a remarkably large amount, while the protein has been reduced to 6.66 per cent., a difference in protein of nearly ten

per cent. Corn is also bred for a large amount of starch, and similarly useful results follow.

The breeding of corn has gone to yet another extreme, the breeder having succeeded in doing away almost entirely with the grain and producing a large, firm cob. These cobs, that are produced on some of the poorest land in Missouri, are used for making the corn-cob pipe, and the introduction of the Collier corn into that district has been a Godsend to the poorest farmers with the poorest lands in the State. A very similar result has recently been obtained in Illinois, where a large firm cob with an insignificant grain has been produced on a soil of nearly pure siliceous sand. It has been found that the pith of the corn cob is a most valuable substance for calking ships and stopping leaks, the pith absorbing water and swelling to fill the crevice, and cobs have been produced with a maximum of pith in the cob.

The corn of our mountain districts is rich in fat, and there too is the only portion of the South where we may raise sugar corn with success. The longer season in the lowlands admits of the elaboration of the fats into proteids. It is interesting to note in this connection that the corn of our mountains and the corn of the north are rich in heat producing elements, while these are almost entirely wanting in Southern varieties of corn, the long growing season admitting of the change of the sugars and fats into proteids. We cannot even raise sugar corn in our coastal plain from the seed of sugar corn grown there, but must get our seed each season from a colder region. The same is true with regard to the seeds of cabbage grown in the South except in the mountain region.

The changes in the character of corn are in no small measure the work of members of the corn-breeders' association, and show what may be accomplished through co-operation among farmers. This association has been working to make corn a complete ration. Here in the South, Williamson has greatly improved corn both as to quality and yield per acre, by a method peculiarly his own. The seed has been planted

and allowed to grow with grass and weeds until the plant has reached a weak maturity and is just ready to bear grain. Then the grass is cleared out, the corn well worked and heavily fertilized, when its stimulated growing energy goes all to fruiting. It has its parallel in the intellectual activity of the boy who comes from the back districts where he had no advantages of an intellectual sort, but his energies being aroused at the right moment, often surpasses his more fortunate associates in his college course and in the race of life.

Some of the most interesting experiments in plant-breeding have resulted in the production of food stuffs adapted to semi-arid regions, and these are of especial interest to us for the reason that we have a long strip of semi-arid land in the South, lying mainly in the sand-hills region and immediately bordering that region on the northwest, little more than a barren sand-waste until the introduction of new methods and new plants suited to its conditions.

Alfalfa has been bred to resist both drought and alkali, and it has also been found in nature. Agents of our Agricultural Department searched the earth for what was needed, and found just the thing desired growing in an oasis of the Algerian Sahara. Luther Burbank has bred a spineless and edible cactus admirably adapted by nature to such regions, and this may yet become an important food plant in certain portions of the South.

Rice forms the principal food of one-half the population of the earth. It is more widely used as a food stuff than any other cereal. Where dense populations are dependent for food upon an annual crop, and the climate admits of its cultivation, rice has become the staple food. The luxuriant growth of leguminous plants (peas, beans, etc.) in warm climates provides the nitrogenous elements necessary to supplement rice. A combination of rice with legumes is a much cheaper complete food than wheat and meat, and can be produced on a much smaller area.

The Carolinas in the decade ending 1860 produced approxi-

mately eighty-five million pounds of clean rice. Now the total product for a like period is only about thirty-five million pounds, of which North Carolina only produced about seven million. But the total rice product of the entire South has advanced from 103 millions to 143 millions in the same time, thanks to the valuable investigations of and improved methods introduced by Dr. S. A. Knapp, of the United States Department of Agriculture.

Horticulture is coming to be a most important branch of agriculture, and its surprising progress has already been so fully discussed in our newspapers and periodical literature that I need do little more than advert to it here. Suffice it to say that in 1870 the export of fruits preserved in cans or otherwise from the United States to foreign countries amounted in value to \$81,735.00. Ten years later the value of the canned fruits exported had advanced to \$371,118.50. In 1890 it was over \$600,000.00, and in 1900 had passed two millions. This does not give us any indication of the enormously increasing domestic consumption of fruits.

It is an interesting fact that the traveler of to-day does not find his way across the desert by the bones of men and beasts that have started on the perilous journey before him, but by the shining tin cans left by those who have made the journey in safety.

This progress in fruit growing has been made possible by the breeding of fruits to suit different climates, and by the importation of insects to prey upon the insect enemies of fruit trees.

Already our trucking interests have made the South the garden of the nation, for we have here the broad coastal plain soils that yield readily to cultivation; but business methods have gone hand in hand with the application of scientific methods and are always equally important to the agriculturist. The managers of the truck-growers' association see to it that the crops come on in regular rotation from Florida, Georgia, the Carolinas, Virginia, and Delaware.

The Strawberry Trust at Selma, a North Carolina organization, has an agent who gets each night reports from all the strawberry eating cities as to the number of crates of berries on hand, and he then learns from the fields how many they can supply, and an effort is made to keep the shipments just a little short of the demand. Then by uniting their shipments and sending them forward in carload lots, the shippers get a better rate and quicker transportation.

Notwithstanding the South produces so much rice, and the entire product of the country, still we produce only half of what is consumed in the United States; but with the improved methods of cultivation, it will be but a short time before we produce enough for the entire nation.

Of corn we can produce every variety from our coastal plain to our mountains, and corn culture is extending about as rapidly as the culture of rice. The culture of wheat is extending as new varieties are being bred for our lands, and wheat culture is extending into regions where wheat has never before been raised. New varieties of potatoes have been produced in our potash soils, and already the best of these are grown in the South, and the rapid extension of their culture will soon make us the most important potato producers in the country.

Of cotton, we have not simply the monopoly of this country, but practically the world's monopoly as well. Experiments carried on at Darlington, S. C., have resulted in the production of a long-stapled cotton that will grow far from the sea islands. And the new methods of tobacco culture are showing us that we can produce all the grades of tobacco, and these in any quantity.

Thus we already have the garden of the nation; we may become, nay, are rapidly becoming the nation's field for the production of food stuffs; and whether we will or no, we will soon be the only forest that the nation has left, except in the national forests scattered over our broad domain.

Forest trees depend more directly upon rock composition

and geological structure than any other products of the soil. This is beautifully illustrated in our State where conifers predominate over the coastal plain and sand hills region, and the broad-leaved deciduous trees over the granitic and schistose rocks farther west. Within these areas species and varieties vary with the changes in character of the rock and the change of its dip helping or hindering drainage. This is beautifully illustrated in the neighborhood of Chapel Hill, where our Triassic sandstones bear the loblolly pines, except where the rocks are cut by dikes, and then you may trace the dike by the broad-leaved trees that grow upon it. The crystallines of the Chapel Hill mass have their characteristic deciduous species, and these again vary as the rock structure changes.

We have in the Appalachians practically the only hard wood forests on the continent, and many of the most valuable species are confined to the Southern Appalachian mountains. In the north these forests have been ruined by the destructive work of the lumberman, before the introduction of the methods of modern scientific forestry; but here we already have the forest of the nation if we will but preserve it, and upon its preservation depend the field and the garden.

Our fathers had a true instinct when they pictured a great civilization in the South based upon the soil. Their vision is to be more than fulfilled when Southern agriculture can bring to its aid science, that sensible science of our day, which has for its ultimate end not merely discovery, but application; which is not so delighted with the formulating of a new law as it is overjoyed at the lifting of a burden. "Then the tiller of the soil will come up to his calling as fully equipped for service as the lawyer, the doctor, the captain of industry; for it has come to pass that the calling in which the unlettered and untrained man was once supposed to have as good a chance as the educated one, is now the calling in which wide and varied knowledge is as imperative as in almost any other known among men."

Men have also come to the same views as those expressed by the King of Brobdingnag, who "gave it as his opinion, that whoever could make two ears of corn, or two blades of grass to grow upon a spot of ground where only one grew before, would deserve better of mankind, and do more essential service to his country, than the whole race of politicians put together."

And better still: While the politician of the not very remote past flattered the farmer and yet made laws directly opposed to all his interests, the new politician in the South shows constructive statesmanship by helping him to take advantage of the opportunities around him, helps him with his inland waterways, helps him to preserve his forests.

SOME INTERESTING GRASSHOPPERS (AND RELATIVES) OF NORTH CAROLINA.

BY FRANKLIN SHERMAN, JR.

The grasshoppers and their relatives comprise the order of insects known as the Orthoptera. The entire order contains probably about 150 species native to North Carolina, of which about 130 have now been collected, identified, and recorded.

There are not many students of Orthoptera in this country and what few entomologists there are in the Southern States have neglected the group entirely, hence practically nothing was known of the actual distribution of our species until 1903, when Prof. A. P. Morse, of Wellesley College, made a special tour through the Southern States to study this subject, and, partially through the entreaties of Mr. C. S. Brimley and the author, he devoted more time to North Carolina than to any other State,—traversing it from east to west and then again visiting the high ranges in the western section. During his tour, Prof. Morse spent two days at Raleigh, at which time Mr. Brimley and the author accompanied him in collecting jaunts with the result that our latent interest in this neglected order was considerably aroused. The facts set forth in this paper have, therefore, for the most part, been collected in the last three or four years, by C. S. Brimley, G. M. Bentley, and the writer.

While no one can seriously study this order of insects without becoming interested in the special structures and their use in classification, as well as in the habits of the living insects,—yet there are about a dozen species which would more particularly arouse the interest or curiosity of the ordin-

ary observer, and to mention these is the special object of this paper.

Labidura riparia. This insect belongs to the family of insects known as the "Ear-wigs". The group is abundantly represented in Europe, but only sparsely in America, the few American representatives, however, being more especially distributed in the Southern States. Most of our ear-wigs are of small size, ranging from one-half to three-fourths of an inch in total length. In mid-April of the present year a janitor brought to the office a living specimen of this species, a fine large male, the first to be taken in the State.

Cryptocercus punctulatus. This insect belongs to the family of roaches, a few species of which infest houses, though more are found in the forest. The present species has been taken in four localities in this State, three of which are in the mountains, the exceptional locality being Newton. It is rather a large species, is entirely wingless, and is rather slow and stiff-bodied in movement, in which respect it differs from most other roaches. Our specimens have all been found under logs, in the months of July, August, and September.

Stagomantis carolina. This creature is most commonly known by the names of "Rear-horse", "Devil's Riding-horse", "Praying Mantis", and other expressive common names. It often arouses curiosity by its peculiar appearance and demeanor. It probably occurs throughout the State, at least east of the mountains, though we have had specimens from only a few localities. It is the only member of the Orthoptera in the State which is known to be predaceous in habit.

Diapheromera femorata. This insect is also known by the name of "Walking-stick", so called because its very slender body gives it a resemblance to small twigs, and because the insect always deliberately *walks*, and never runs or jumps. All through the summer the young insects are greenish in color, corresponding to the color of young twigs and the petioles of

leaves among which they live, but in the autumn when the leaves fall and the twigs become gray or brown, these insects, being then near maturity, turn gray in color. These remarkable resemblances, combined with their deliberate movements, render them quite difficult to detect, unless they force themselves accidentally upon one's notice.

Eritettix navicula. This is one of the true grasshoppers, which so far as has been observed inhabits rather low, grassy grounds. It is an exception in that it is the only species which has the antennae enlarged into a knob or club, at the tip.

Trimerotropis saxitalis. This very remarkable grasshopper is an inhabitant of the exposed, lichen-covered surface of the rocks on some of our mountains. In his trip through the Southeastern States Prof. Morse failed to take it in this State, but recorded its presence on the summit of Stone Mountain, in Northern Georgia. In September last (1906) Mr. Woglum and myself took it quite commonly in favorable spots on the summits of Satula and Whiteside Mountains, near Highlands, Macon County. The species bears a remarkable resemblance to the lichen-covered rocks on which it is found, and when flushed will invariably settle again on the rock, it being only in most exceptional cases that they could be persuaded or forced to alight in grass or herbage. When cornered they would quickly fly back within a foot or two of the collector to again reach the rock, although the species is quite shy when once disturbed.

Leptysma marginicollis. This species is found in grassy places where it clings to the upright stalks or blades, so closely applying its body to the grass as to render detection difficult, both the shape and color of the insect being protective. One remarkable feature of this insect is the fact that the front of the head (or face) slopes away under the body in such degree that the mouth is situated almost between the front legs.

Melanoplus punctulatus. The genus *Melanopsus* contains many species, the majority of which are not especially striking in appearance or habits, but this species is an exception in that, while all the other species habitually live on the ground or on low-growing grass or herbage, this one is considered to be strictly arboreal, occurring on trees, stumps, shrubbery, etc. Our one specimen of this species was taken in Transylvania County by Mr. Woglum, and is mottled in appearance, which renders its color protective when on lichen-covered bark. It is likely that the species does not occur east of the mountains in this State.

Dissoteiria carolina. This is one of our most common grasshoppers, and in nature (if not in the cabinet) is surely familiar to most observant country people in this State. Among those who have any common name for it, it is known as the Carolina Locust. It occurs throughout the State along roadsides and in cultivated fields. The remarkable thing about this species is the variability of its protective colors. In sections where the soil is grayish in color there the insect is grayish, while only a mile away may be found red clay soil and grasshoppers of a decidedly reddish tinge. Not that the resemblance is perfect, but the difference in color of specimens taken on differently colored soils is quite noticeable. On one occasion in Raleigh I took a specimen on a railway embankment and the greater portion of the body was blackish to correspond to the soot and cinders among which it was found. No similarly colored specimen has since been taken anywhere, and others were not seen at that time.

Gryllotalpa borealis. This is commonly known as the "Mole-cricket", so called from its habit of burrowing in the ground like a mole, and from the further fact that it has developed along very similar lines, the front limbs being much enlarged like the front paws of the mole, and like them are used for digging.

Myrmecophila pergandei. This small and wingless cricket

is found beneath stones in company with ants, whose nests they inhabit, and in consequence of the darkness prevailing in its usual haunts, is white in color. Thus far it has been taken only at Raleigh, though doubtless it occurs in other localities.

Tridactylus sp. This is a small, blackish species taken at Raleigh early this month for the first time. It was found in low, sandy ground in which it frequently disappeared down very minute burrows. When disturbed or alarmed they jump with marvelous agility, their small size causing them to instantly disappear from view when they once leap away. After capturing several specimens by laboriously approaching them with the killing bottle, we finally began to walk rapidly over the ground and sweep the collecting net back and forth at random, and by this means secured them in considerable numbers.

NOTES ON SOME TURTLES OF THE GENUS PSEUDEMYIS.

BY C. S. BRIMLEY.

The genus *Pseudemys* comprises a number of large fresh water turtles found in the streams and ponds of North America. These have the carapace marked with a more or less variegated pattern of light and dark colors, and are distinguished from allied genera by the broad masticating surfaces of the jaws, which are in the upper jaw divided by a longitudinal ridge parallel to the margin.

The species dealt with in this paper fall more or less naturally into three groups, which are characterized as follows:

GROUP I. Upper jaw with a notch at the symphysis and a cusp or tooth on each side of the notch. Lower jaw, at least, strongly serrated. Ridges in masticating surfaces of jaw tuberculate.

GROUP II. Upper jaw without either notch of cusps, otherwise as under Group I. Plastron always yellow, unblotched.

GROUP III. Upper jaw notched at symphysis, but without cusps. Edges of jaws not serrated. Ridge in masticating surface of jaws not tuberculate.

Group I comprises three nominal species, *P. rubiventris* LeConte, *P. alabamensis* Baur, and *P. texana* Baur. Of these the first and last are certainly distinct species, but the second, of which I have seen no specimens, may be the same as the first.

Of *P. rubiventris* I have seen only one specimen, this be-

ing a live individual from Orlando, Florida, which measured 267 mm. over curve of shell, 245 in straight line, 167 in greatest breadth, 110 in greatest height. Shell strongly arched. Carapace black with red markings, marginal plates with much red below, plastron yellowish brown, but reddish in front and behind, legs with red stripes. The head markings I couldn't see, as he would not put his head out. Lower jaw very strongly serrated, with a serrated cusp at tip; upper jaw slightly serrated, with a median notch and a strong cusp on each side of it. Date, March 16, 1902.

Alabamensis, according to Baur,* has the shell more arched than in *rubiventris*, and the plastron is yellow with brown markings, instead of red as in *rubiventris*.

Of the third species of Group I, *P. texana*, I have seen only two undoubted specimens, one a living specimen from Colmesneil, Texas, measuring 284 over curve of shell, and 265 in straight line; greatest width 215. Shell smooth, not wrinkled, and without traces of a keel. Color slaty brown with yellowish markings, the markings on the costal plates transverse to the longitudinal axis of the shell. Marginals each with a vertical yellow bar down the center. Plastron yellow without markings. Both jaws serrated, the lower much the most so; upper jaw notched in front but without cusps. Date, July 7, 1902.

The second specimen, which was from Shell Bank, La., was much the same color, and had the upper jaw notched in front, with a slight cusp on each side of the notch. Other characters, as in the first specimen. Length in straight line 225, width 150. Date, July 27, 1903.

Group II includes five nominal species, *P. concinna* LeConte, *P. mobiliensis* Holbr.,† *P. floridana* LeConte, *P. hieroglyphica*,

* "Notes on the classification and taxonomy of the Testudinata, part IV, The species of the genus *Pseudemys*" by G. Baur. (Proc. American Philos. Soc. XXXI, May 5, 1898).

† According to Dr. Baur (*loco cito*), *P. mobiliensis* Agassiz is not the same as *P. mobiliensis* Holbr., the former being a composite species equaling *P. alabamensis* Baur plus *P. texana* Baur.

Holbr, and *P. labyrinthica* C. Dumeril, but how many species it really contains I don't know, as individual variation in at least one species seems quite wide and obliterates the distinctive features ascribed to most of the others.

According to Dr. Baur (*loco cito*) these species are characterized as follows:

Concinna by its broad and low shell and its small head.

Hieroglyphica by its elongated, narrow shell and its head, which is still smaller; the yellow stripes and dots on the head are also very much more expressed than in *concinna*.

Labyrinthica shows the coloration of head and neck of *hieroglyphica*, but the head is larger and the shell more as in *mobiliensis*, but by far not so large.

Mobiliensis has the head like *concinna*, but larger, the shell very much more arched especially in front, the animal much larger than in *concinna*, the upper shell reaching a length of 385 over the curve.

Floridanus is at once distinguished by its oval form and the great elevation of the carapace and its color. The carapace has a very dark brown color with numerous irregular lines of yellow. The marginals are dark brown and have only one vertical, median yellow line, and are without the yellow concentric lines so characteristic of *concinna* and *mobiliensis*. The carapace is much more arched than in *mobiliensis* and nearly forms a half circle. The skull is also larger than in this species and the jaws are not serrated (*sic*).

The characters quoted above, except those for *floridanus*, all fall within the range of individual variation of Raleigh specimens of *concinna*, and hence until I am able to examine specimens of the others, I cannot help feeling doubtful of their validity.

Raleigh specimens of *concinna* present the following characteristics: The carapace is marked with a variegated pattern

of brown and yellow lines, these forming more or less distinct concentric figures, parts of three of which usually enter each costal plate. Markings of the carapace usually not definitely transverse to the axis of the body, on the costals. Marginal plates marked above with a median, vertical, yellow bar, and yellow concentric figures between the yellow bars of adjoining plates; quite frequently, however, the vertical bars are absent on some of the plates and the concentric figures replaced by longitudinal yellow lines, continuous on adjoining plates, this occurring on the middle and posterior marginals, but not usually on the anterior ones. In seven adults this feature is present or absent as follows: In one the longitudinal lines replace the vertical bars and concentric lines on all the marginals; in two others they do not occur at all; in a fourth they occur only on marginals 4, 5, 6, right, and 11, 12, left; a fifth has them on the four middle marginals on each side; a sixth on numbers 5, 9, 7, right, and 6, 7, left; a seventh, on numbers 4, 7, 8, 9, 11, on both sides, and on No. 12, right also. The presence of a vertical yellow bar across the center of each marginal is so constant in all specimens of *Pseudemys* that I have seen, except those from Raleigh, that the variation seems worth noting. Head and legs with yellow stripes. Plastron yellow, unblotched.

In the shape of the shell there is also a good deal of variation, some specimens being broad and flat with a median, dorsal depression; others are broad and flat but lack the dorsal furrow, while others again have comparatively high and arched shells, and in any case the dorsal depression is only present in full grown specimens, not in young nor in half grown ones. The flat shelled specimens seem to be mainly males, and the more arched ones females, but I have not examined enough specimens to be sure that the variation is wholly sexual and not individual.

The size of the head also varies, being large in some specimens and small in others, the difference being apparently

sexual, the small headed ones being males,* the large headed ones females. Young specimens are nearly circular with a distinct dorsal keel, as in all young *Pseudemys*, but a specimen 130 mm. long has substantially the form of the adult.

Some measurements of specimens from Neuse River near Raleigh are as follows:

	Taken.	Greatest Length.	Width.	Height.
1.	Feb. 26, 1902, sex?	131	107	55
2.	April 23, 1906, male	150	114	54
3.	March 29, 1904, female	161	—	—
4.	July 27, 1903, sex?	202	139	—
5.	March 24, 1903, male	211	150	82
6.	March 29, 1904, female	240	158	—
7.	June 2, 1905, sex?	240	172	80
8.	March 24, 1903, female	275	185	110
9.	March 16, 1902, sex?	280	195	107

Of what Baur called *mobiliensis*, I have had one adult and several smaller specimens from Baker County, in Southwest Georgia, but while the adult has an arched shell and is a little larger (290 mm. long) than the largest I have measured from Raleigh, its shell is not more arched than those of some Raleigh specimens, nor is the head larger than in some of them. In coloration it is identical with Raleigh specimens, as are also the young ones, except that none of them have any vertical yellow bars and concentric markings on the marginals replaced by longitudinal yellow lines. I am inclined to consider this form as merely, at the most, a large southern form of *concinna*.

Of *floridana* I have had three good sized adults from Johnston County, N. C., and quite a number of small and half grown specimens from Southwestern Georgia, and Florida. These differ from *concinna* in usually having a vertical yellow

* See also "Some observations on the turtles of the genus *Malacemys*" by O. H. Hay, (Proc. U. S. N. M., Vol. XV, No. 908) in which he states that the females of this genus have larger heads than the males.

bar, forking at the upper end, down the center of the first and second costal plates, and in having the markings on the rest of the shell less concentric and usually in larger pattern. The marginal plates have a vertical yellow bar down the center of each, with concentric markings between; these latter, however, only occur in quite small specimens, as they disappear early in life leaving only the vertical bar. Head, legs, and plastron colored as in *concinna*. Ground color of carapace dark brown, darker than in *concinna*. The really important difference lies, however, in the shape of the shell, which is shorter and more arched than in *concinna*, being in fact more nearly the shape of that of *P. scripta*, to which species *floridana* bears a superficial resemblance. The males have smaller heads and lower shells than the females.* The upper jaw is slightly, the lower jaw strongly, serrated, in all specimens that I have seen,

The measurements of the shells of some specimens are:

Taken.	From.	Length.	Width.	Height.
1. June 20, 1905,	Johnston Co., N. C.,	250	197	110
2. June 30, 1905,	" "	222	149	95
3. June 30, 1905,	" "	169	—	—
4. May 14, 1904,	Baker Co., Ga.,	136	114	57
5. July 20, 1904,	" "	150	—	—

I have seen no specimens of *labyrinthica* or *hieroglyphica* and the characters assigned to them by Dr. Baur (*loco cito*), are not of specific value, as they fall within the range of the individual variation of *concinna*. As *labyrinthica* is smaller than *concinna* and *mobiliensis* larger, it is quite possible it is a smaller† northern race of that species, just as *mobiliensis* appears to be a larger southern race.

* According to Dr. Baur (*loco cito*) *floridana* does not have serrated jaws, but he places it in a section of the genus with lower jaw strongly serrated, so the absence of serrations probably applies only to the upper jaw, where they are little evident.

† *Labyrinthica* occurs in Tennessee and Illinois in the tributaries of the Mississippi.

Group III comprises three species which agree in having the upper jaw with a notch at the symphysis, but without cusps on each side of the notch, in the edges of both jaws being without serrations, in the ridge in the masticating surface of the jaws being non-tuberculate, and in the plastron being more or less blotched. These three are *scripta* of the Southeastern United States, and *elegans* and *troostii* of the Mississippi Valley and southwestward.

The three may be distinguished as follows:

1. Carapace keeled at all ages, a vertical yellow bar just behind eye. *Scripta*.

Carapace not keeled in adult, no vertical yellow bar behind eye.

2. An elongate-oval red mark on neck behind eye. *Elegans*.

No oval red mark on neck. *Troostii*.

Scripta is a large, heavily-built terrapin, with a wrinkled shell, and a distinct dorsal keel at all ages. A diagnostic mark of this species is a vertical yellow figure just behind the eye. The marginals are marked as usual in the genus with a vertical yellow bar and concentric figures between; the latter, however, are usually absent in adults. The carapace is marked on the costals with yellow, black and brown markings, there being usually a central yellow stripe down the middle of each costal with yellow and brown lines parallel to it and meeting their fellows above its upper end, and to some extent below its lower end; the black is more irregular in amount and position than the other colors, but there is always some black on each plate in the adult, although it is wanting in young specimens. On the posterior costals the markings are less regular and more confused. The plastron is yellow, or occasionally brownish, with a round black spot on each of the two anterior plates; often there is a black spot on the next two plates also, and occasionally one on every plate.

The largest specimen I have seen weighed seven and a half pounds and measured 272 mm.

Elegans is much like *scripta* in general appearance and in markings, but the shell is flatter and not keeled in the adult and the red neck spot is characteristic at all ages. The markings on the carapace are variable, but usually much as in *scripta*, but those of the plastron are different, each plate usually containing a black or dusky spot which is usually surrounded by one or more dusky concentric lines.

Of *troostii* I have only seen one specimen and that differed greatly in many respects from all the specimens of *scripta* and *elegans* that I have seen. It was from St. Louis, Mo., and measured 185 in length and 137 in breadth, and the tip of the nose extended 107 mm. beyond the front edge of the shell, when the neck was stretched to its fullest extent. The upper jaw was notched in front, lower jaw pointed at tip, neither serrated. Both upper and lower jaws much wider and more rounded than in any other *pseudemys* with which I am acquainted, especially than in *elegans* and *scripta*, which have the snout notably pointed. Head dark above with narrow, pale stripes; chin, throat, and neck below, light colored with rather pale darker stripes on neck below, much as in *Deirochelys reticulata*. Shell rather flat on top, rounded off on sides, rather deep, and much the shape of *Deirochelys*, but the bridge and shell not so high; shell smoother and without the wrinkles so characteristic of *Deirochelys*. Carapace dark brown with indistinct paler markings, most of the marginals with faint vertical bars which are barely visible. Plastron pale with some dark markings round the edges of the plates. Superficially and in length of neck this specimen resembles a *D. reticulata* more than it does the other species of *Pseudemys*, but I found on examination that the basal portion of the ribs was short, straight and broad as in other *Pseudemys*, not long, slender and arched as in *Deirochelys*.

SPECIMENS EXAMINED.

- P. rubiventris*, Orlando, Florida, one.
- P. texana*, Colmesneil, Texas, one; Shell Bank, La., one.
- P. concinna*, Raleigh, N. C., nine adults and several young.
- P. mobiliensis* (= *P. concinna*?), Mimsville, Ga., one adult, two young.
- P. floridana*, Johnson County, N. C., three adults; Orange County, Fla., two young; Mimsville, Ga., two half-grown specimens and several young.
- P. scripta*, numerous specimens from Raleigh, N. C., and Mimsville, Ga.; Lake Ellis, N. C., several.
- P. elegans*, Austin, Texas, three; St. Louis, Mo., three; Shell Bank, La., one.
- P. troostii*, St. Louis, Mo., one

THREE LITTLE KNOWN SPECIES OF NORTH CAROLINA FUNGI.

BY J. G. HALL.

It is my purpose to take up three species of fungi that are little known in North Carolina, and in fact in the United States, and to give a brief description of them.

The first two belong to the Hyphomycetes of Saccardo, but to different groups under this head. The third belongs to the Pyrenomycetes, and the family Sphaeriaceae.

The first I have preferred to call by the known name of *Martensella pectinata*, although as will be seen later, there are sufficient differences to make it a new species. It was first described by Coemaus in 1863 from Belgium.

This fungus is new to North Carolina, and in so far as I have been able to determine, has not been reported in print from the United States, although I know it to be in culture in one other place than West Raleigh.

The discovery of this species was partly an accident. Last December I was making some plate cultures from some soil that came from New Bern, in the eastern part of the State, for *Sclerotinia*, a lettuce disease upon which we have conducted a series of experiments.

In the culture I noticed growing a fungus that at first I took to be *Botrytis*, but upon microscopic examination found to be *Martensella*.

The fruiting hyphae stood erect and unbranched, except for the short spore bearing stalks, although later I found that the fungus became branched, and some times very much so.

The erect hyphae are septate and after arising a short distance above the substratum each cell sends out a short branch near the outer end. These short branches become the sporophores, and at first are indistinguishable from the main hypha except in size. Almost immediately the tips of the sporophores bend upward at approximately right angles and the portion beyond the bend rapidly becomes closely septate, having six to nine septae. The sporophores very soon become boat-shaped with the keel toward the main hypha. Upon the side away from the main hypha there arise small protuberances, the first appearing nearest the bend, and then being produced in succession toward the tip.

These growths early begin to show a slight swelling, forming a kind of head at the tip, which later lengthens into the fusiform spores; these are constricted into a very fine thread at the base, which connects them with a swollen base (basidia) that joins them to the naviculate sporophore.

Saccardo places this fungus in that group of the Hyphomycetes called the Mucedineae, because of the looseness and lightness of color of the mycelium. Also among the Amerosporaeae of the latter, because of the shape and color of the spores.

In quoting the original description in his *Sylloge Fungorum* Saccardo says that the sterile hyphae are procumbent, with the fertile erect, with both branched and septate; the spores are borne on short lateral branches and in two rows along the face of the naviculate sporophore, being cylindric-fusiform in shape, and measuring $10-20 \times 3 \mu$; that it is parasitic on *Muco* and the *Saprolegneae*. After giving the habitat a note is added saying that Cremans describes some of the spores as being borne in chains, and Engler & Prantl reproduce figures of the fungus which show some of the sporophores bearing catenulate spores, which are nearly globose in shape.

After the note Saccardo makes the very significant remark that the appearance of the catenulate spores is exceedingly strange.

Engler & Prantl also show the sporophores with the spore-bearing surface upward and inward.

In the early part of this note I said that I believed I would be justified in making a new species on account of the differences I found between my specimens and those in Saccardo and Engler & Prantl. I found: that the plant grew very freely with *Penicillium* as a host; that the spores are never borne in chains but always singly; that instead of being borne in two rows along the face of the sporophore, they are arranged all over its surface. In other respects my specimens agree with the descriptions noted.

The second species that we consider is one of the Genus *Epicoccum*, which belongs to the *Tuberculariae*, another group of the *Hyphomycetes*, so called because the mycelium forms a tubercle or mass of threads from which the spores arise.

The spores are borne in masses almost without sporophores, but what there is of them is light brown, although the greater part of the Mycelium is white. The spores are black when mature but brownish black in the younger stages. They are rough on the surface and look very much as if they were four-celled, but I have not been able to see any definite partitions. They are globose and measure from twenty to thirty μ in diameter.

In germination the spores send out short, almost globose cells, and after forming two or three of these at each point of germination, they grow into the regular septate hyphae, which continue to lengthen for some time.

Near the growing tip of the mycelium short branches arise, at first just a single filament, but very soon becoming much and irregularly branched, forming a hemispherical mass (sporodochium) upon the surface of which the spores are borne.

As an experiment this fungus was grown upon several different kinds of media to see if different nutrients had different effects upon it.

A medium which we called C. B. A., Chemical Base Agar, was made as follows: Water, 1000 grams; Di Potassium-phosphate, 2.5 grams; Calcium Chloride, 01 gram; Magnesium sulphate, 01 gram; Sodium Chloride, 2.5 gram; Potassium sulphate, 2 grams; Agar, 15 grams.

To this was added Sodium Aspariginate in one case; Sodium Aspariginate and Starch in another; Sodium Aspariginate and glucose in another, and one or two others. Four per cent. Pea Agar and Apple-twig Agar were also used.

On the Pea Agar the Mycelium was white with very few pink spots; upon the Apple and Apple-twig Agar the Mycelium was orange yellow with abundance of pink spots. Upon C. B. A. and N. A. S. and N. A. G. the Mycelium was white but with a large number of large pink spots. In all cases spores were formed in equal abundance and they were most numerous near the point of inoculation.

The third and last species belongs to a very different group of fungi, the Pyrenomycetes, which has its spores borne in sacs (asci) within closed or nearly closed conceptacles called perithecia. In giving the systematic position of this species, I shall follow Ellis & Everhart's North American Pyrenomycetes.

This is a new species of fungus, but I hesitate to give it a name because of the scarcity of material. It is one of the Genus *Podospora*, in the family *Sordariaeae*, which is one of the sub-order *Sphaeriocaeae*.

The perithecia are borne singly and scattered, are black and flask-shaped. The asci are clavate and bear the eight spores which are the distinguishing feature of the plant. They are dark, elliptical, and are joined by a filament into pairs.

So far as I have been able to learn, there is only one species that approaches this in any way, and that is *Podospora zygospora*, in which the spores are similarly joined in pairs, but the thread joining each pair is septate, while in this one there are no septae in the connecting thread.

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PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY, JANUARY 1907 TO
OCTOBER 1907.

169TH MEETING, JANUARY 15, 1907.

H. V. Wilson: The Regenerative Power of Sponges.

J. W. Gore: Direct Current Transmission of Power.
The Electrical Aging of Flour.

170TH MEETING, FEBRUARY 12, 1907.

J. H. Pratt: The Fish and Oyster Industries in North Carolina.

Collier Cobb: Some Human Habitations.

171ST MEETING, MARCH 19, 1907.

J. E. Latta: Some Recent Developments in Electric Traction.

N. C. Curtis: Architectural Composition.

172ND MEETING, APRIL 16, 1907.

Archibald Henderson: The Foundations of Geometry.

Chas. H. Herty: The Optical Rotation of Turpentine.

At the close of the program a business meeting was held to consider the programs. It was voted that a minimum of four meetings be held each year but, if possible, one meeting per month.

sun should be avoided. Tubs answer as well as concrete aquaria, and have the advantage of being movable.

In a day or two the oscula of the sponge disappear, and the surface begins to acquire a peculiar smooth, dense and uniform appearance. Microscopic study reveals the fact that not only the oscula, but the pores also, for the most part close, and the canal system becomes interrupted and in some degree suppressed. The mesenchyme is more uniform, and is denser than in the normal sponge, owing in part at least to the disappearance of the extensive collenchymatous (very watery mesenchyme) tracts of the latter.

The whole sponge may pass into this state and remain without great change for weeks. During this period it shrinks greatly in size, in a given case to one quarter the original bulk. The arrangement of the skeletal spicules becomes much simplified. With the shrinkage in size the sponge becomes more solid, *i. e.*, more of the canal space is suppressed. Some flagellated chambers persist and there are a few small scattered apertures on the surface. The bulk of the chambers disappear as such, the collar-cells transforming into simple polyhedral masses which become scattered singly or in groups in the general mesenchyme. The mesenchyme is a syncytium composed of well-marked cells that are freely interconnected. The sponge in this condition closely resembles *Spongilla* in its winter phase, as described by Weltner.* Presumably water continues to circulate through the body, but the current must be an exceedingly feeble and irregular one.

As a sponge in this condition continues to shrink, it may subdivide and thus a large sponge may eventually be represented by numerous masses, in a given case about 1 cm. in diameter. Now if the sponge in this condition or if one of the masses into which it has split up, be attached to wire gauze and suspended in a live box floating at the surface of the open water of the harbor, the sponge or piece will in a few days grow and redevelop the pores and oscula, flagellated chambers, tissue differentiation, and skeletal arrangement of

2 'Spongillidenstudien, II. Archiv für Naturgeschichte,' 1893.

the normal sponge. Whether in this regeneration the transformed and separated collar cells again unite to form the flagellated chambers, I can not say. I think it very doubtful.

In the two classes of cases just described the sponge as a whole degenerates and slowly shrinks. Cellular death takes place so gradually that at no time is there any obvious corpse tissue or skeletal debris. Much more common and of far greater interest are the following cases. In these a large part of the sponge body dies in the course of two or three weeks, leaving the skeletal network still in place and bearing the brown decaying remnants of the flesh, which, as maceration continues, are washed away. In places, however, the sponge body does not die. Here masses of living tissue are left, conspicuous amidst the dead remains by their bright color and smooth clean surface. These living fragments may be classified into three groups. First, the upper end of an ascending lobe or a considerable part of the body of the lobe may be left alive in its entirety, thus forming a more or less cylindrical mass up to 5 mm. diameter, with a length sometimes two or three times the thickness. The histological condition of these masses is not very different from that of the sponges already described. Such a mass may be said to consist of anastomosing trabeculae, separated by the remains of the canal system. The mesenchyme composing the trabeculae consists of discrete cells interconnected by processes to form a syncytium. The flagellated chambers as such have nearly disappeared, although remnants may still be recognized. In them the collar cells have transformed into simple polyhedral bodies that are widely separated. The bulk of the chambers have broken up into their constituent cells, and these are now scattered as elementary parts of the general mesenchyme. When such masses are attached to wire gauze and hung in a floating live-box they transform into perfect sponges.

A second class of surviving remnants includes masses scattered over the general surface of the sponge. These may be spheroidal and small, less than one millimeter in diameter. Usually they are flattened and of an irregular shape with

lobes, suggesting a lobose rhizopod or myxomycete plasmodium. Such masses which may be connected by slender strands are commonly from two to five millimeters in the longest direction. The third class of remnants are found scattered through the body of the dead and macerated sponge, in which they sometimes occupy positions that are obviously favorable for respiration. These bodies are more or less spheroidal and small, their diameter varying commonly from one half to one and a half millimeters. In the most successful cases of treatment, the small masses, internal and superficial, are exceedingly abundant, and the dead and macerated sponge body with its contained nodules of conspicuous living tissue strongly suggests a *Spongilla* full of gemmules.

These living remnants of the sponge (bodies of the second and third classes) execute slow amœboid changes of shape and position, behaving thus like plasmodia, and they may be designated as plasmodial masses. Microscopic examination shows them to be of an exceedingly simple character, without canal spaces or flagellated chambers. The mass does not consist of discrete cells, but is an aggregation of syncytial protoplasm studded with nuclei. The protoplasm is stored with minute inclusions and is reticulate in arrangement. The nuclei are practically all alike, and there are no signs of persisting collar-cells. Such a mass represents a portion of the original sponge in which the degenerative changes have progressed farther than in the larger remnants. In the latter we find a syncytium made up of discrete cells among which some persisting collar-cells are distinguishable. But in the plasmodial mass the cells have united so intimately that cell-outlines have been wiped out, and recognizable collar-cells (or their nuclei) have disappeared. The optical evidence points to the conclusion that the latter help to form the general syncytium, undergoing regressive changes in their differentiation which result in their becoming indifferent parts of this unspecialized tissue.

The plasmodial masses remain alive in the laboratory indefinitely, but do not transform. They attach to the bottom

of the vessel, but so feebly as to be easily shaken loose. In order to see if they would transform when returned to natural conditions, I devised the simple plan of enclosing them in fine bolting-cloth bags which were hung in a live-box floating in the harbor. The bags, rectangular, were divided into compartments about an inch square with the two flat sides nearly touching. In each space an isolated plasmodial mass was inserted, and the bag sewed up. It was found that in such bags the masses were held in place long enough for them firmly to attach to the bolting cloth. Once attached to the cloth they grow, sometimes quite through the wall of the bag to the outer water, and transform into perfect sponges with osculum, canals, pores and flagellated chambers in such abundance as to be crowded.

This ability to undergo—when the environment is unfavorable but not excessively so, regressive changes of differentiation resulting in the production of a simpler, more uniform tissue, is something that is plainly useful, *i. e.*, adaptive. In the simplified state the sponge protoplasm withstands conditions fatal to such parts of the body as do not succeed in passing into this state, and on the return of normal conditions again develops the characteristic structure and habits of the species. That this power is exercised in nature there can scarcely be a doubt, since the conditions that are present in an aquarium must now and then occur in tidepools.

It is probable that the power thus to degenerate with the production of masses of regenerative tissue is general among sponges. I first discovered the phenomenon in *Microciona*, a very different form from *Stylotella* and one in which the skeleton includes much horny matter. And in two other Beaufort species I have succeeded in producing the plasmodial masses. There is every reason for believing that the commercial sponge shares in this ability. If this is so, we have here a means of propagation which with a further development of methods may at some time become economically practicable. In any case it is now possible to study the differentiation of a quite unspecialized tissue, one that is physi-

ologically embryonic, into a perfect sponge at any time of the year irrespective of the breeding season. We may even exercise some direct control over the size of the plasmodial masses, as the following experiment shows.

Microciona was kept in aquaria until the degenerative process had begun. Pieces were then teased with needles in a watch glass of sea water in such a way as to liberate quantities of cells and small irregular cell-agglomerates. These were gently forced with pipette to the center of the watch glass. Fusion of cells and masses, with amoeboid phenomena, began at once, and in half an hour quite large irregular masses existed. In the course of a few hours the masses grew enormously through continued fusion. From this time on they adhered firmly to the glass, retaining irregular plasmodium-like shapes, and the growth was inconspicuous. To bring them together once more and induce further fusion they were on the following day forcibly freed, with pipette and needle, and to clean them of cellular débris and bacteria were transferred to a tumbler (covering with bolting cloth) in which they were kept actively moving under a fine glass faucet for about thirty minutes. In the course of this violent agitation a good many masses were lost. Those remaining in the tumbler became in the next few hours noticeably rounder and smoother at the surface. From this experiment eighteen more or less spheroidal masses were obtained, some of which measured one half millimeter in diameter. They were similar to the small plasmodial masses produced in this species (and in *Stolotella*) when the sponges are allowed to remain quietly in aquaria. As already stated, it is only in *Stylotella* that I have directly proved the regenerative power of these masses.

Maas has just announced³ that calcareous sponges (*Sycons*) when exposed to sea water deprived of its calcium undergo

3 'Ueber die Einwirkung karbonatfreier und kalkfreier Salzlösungen auf erwachsene Kalkschwämme und auf Entwicklungsstadien derselben. Archiv für Entwicklungsmechanik der Organismen,' Bd. XXII., Heft 4, December, 1906.;

marked degenerative changes, which may be of such a character that the living tissue quite separates from the skeleton and breaks up into compact cords of cells showing active amoeboid phenomena. The cords further constrict into rounded masses the likeness of which to gemmules is pointed out. Maas states that he is not yet in a position to say whether these masses have the power to transform into sponges, but adds that some of his observations induce him to believe that this is possible.

It is evident that Maas, working on very different forms, has independently met with the same degenerative-regenerative phenomena as are described in this communication, the essential facts of which were presented (together with an exhibit of gemmule-like degeneration masses and young sponges into which such masses had transformed) at the recent December meeting of the American Society of Zoologists. I may add that more than two years ago at the end of the summer of 1904, in my official report (unpublished since the research was still in progress) to the Bureau of Fisheries on the investigation under my charge, I described the degenerative phenomena in *Microciona* and *Stylotella*, i. e., the formation under certain conditions of confinement of minute masses presenting a likeness to gemules, and emphasized the probability that these masses were able to regenerate the sponge. It was not, however, until the summer of 1906 that I was able to demonstrate the truth of this view.

UNIVERSITY OF NORTH CAROLINA.

CHAPEL HILL, N. C.,

February 16, 1907.

THE CONDENSATION OF CHLORAL WITH PRIMARY AROMATIC AMINES. II.*

BY ALVIN S. WHEELER.

A number of condensation products of chloral with primary aromatic amines have already been described. The first mention of such a reaction is probably that of Maumené¹ who hoped to obtain indigotine by the action of chloral (2 mols.) upon aniline (3 mols.). His product was a brownish black uncrystallizable substance containing no chlorine. Schiff and Amato² first describe a condensation product of chloral (1 mol.) and aniline (2 mols.) with the formula



In the same year Wallach³ describes this compound. Later⁴ he gives a full description of the products obtained from aniline, p-toluidine, and a sample of xyloidine boiling at 212°-216°. Eibner⁵ studied the condensation of chloral with p-nitraniline, m-chloraniline, p-chloraniline, and 1, 2, 4-dichloraniline and showed that 1, 2, 4, 6-trichloraniline and 2, 6-di-

*Contribution from the Chemical Laboratory of the University of North Carolina.

¹[Ber. 3. 246, (1870)].

²[Gazz. chim. ital. 1,376 (1871)].

³(Ber. 4. 668).

⁴(Ann. 173,274).

⁵(Ann. 302,235).

chlor-4-nitraniline do not react. Wheeler and Weller⁶ prepared the *o*- and *m*-nitraniline compounds and Wheeler and Daniels⁷ showed that only addition products could be obtained with the naphthylamines. Niementowski and Orzechowski⁸ found that one molecule of chloral condensed with one molecule of anthranilic acid but later⁹ obtained the expected diphenamine compound. Finally Rügheimer¹⁰ describes the compounds with *o*- and *p*-phenylenediamine and 1, 2, 4- and 1, 3, 4-toluylenediamine. He also states that only addition products are obtained with the naphthylamines.

The chloral diphenamine compounds vary considerably in stability. Most of them may be kept for years. They possess great crystallizing power. Their behavior toward alkalis is variable. The aniline derivative is decomposed by alcoholic potash into aniline, chloroform and phenyl cyanide according to Wallach. The *p*-nitraniline derivative is converted by alcoholic potash into an hydroxy compound, one chlorine being replaced by the hydroxyl group according to Wheeler and Glenn¹. They are not stable in the presence of strong mineral acids. These split the compound so as to reform the amine. Eibner has shown that boiling acetic anhydride and benzoyl chloride give the acetyl or benzoyl derivative of the original amine. I have found that all of them react with great readiness with bromine in the cold. There is a substitution of one hydrogen atom in those which have been analyzed. This substitution probably occurs in the methylene group of the chloral residue.

With the exception of the anathranilic acid products the following are thought to be new.

⁶(Jr. Am. Chem. Soc. 24, 1063).

⁷(Jr. Elisha Mitchell Sci. Soc. 22, 90 (1906).

⁸(Ber. 28, 2812).

⁹(Ber. 35, 3898).

¹⁰(Ber. 39, 1653).

¹(Jr. Elisha Mitchell Sci. Soc. 19, 63, 1903).

CHLORAL AND p-BROMANILINE.

Trichlorethylidenedi-p-bromphenamine,

With C. W. Miller. Ten grams of p-bromaniline were dissolved in 50cc benzene and 8 grams of chloral (4.2 grams required by theory) in 10cc benzene were added. The mixture was concentrated one-half on the water bath and cooled. A white flocculent precipitate came down. This gave a melting point of 135°. On further evaporation a second crop was obtained, showing a melting point of 119°. By several recrystallizations from benzene the melting point was raised to 140°. The yield of the crude product was quantitative.

Analysis:

0.1588g substance gave 0.2049g CO₂ and 0.0352g H₂O.

0.1638g substance gave 9cc nitrogen at 15° and 755mm.

0.0890 substance heated with 0.3274g AgNO₃ required 9.8cc NH₄SCN (1cc = 0.0173g AgNO₃).

	Calculated for C ₁₄ H ₁₂ N ₂ Cl ₃ Br ₂	Found
Carbon	35.45	35.03
Hydrogen	2.34	2.46
Nitrogen	5.93	6.38
Chlorine + bromine	56.24	55.58

Trichlorethylidenedi-p-bromphenamine consists of fine colorless needles, melting at 140° and decomposing at 205°. It is extremely soluble in alcohol, acetone, glacial acetic acid and hot benzene. It is sparingly soluble in cold benzene and insoluble in ligroin. It is readily purified by using a mixture of benzene and ligroin. It is not decomposed by boiling water but is split by boiling concentrated hydrochloric acid with the regeneration of p-bromaniline. A bromo derivative is easily obtained by adding bromine to a glacial acetic acid solution. The product, consisting of plates, melts at 203°

after several recrystallizations from glacial acetic acid. Determinations of carbon, hydrogen and nitrogen give very satisfactory figures for a monobrom compound. A study of its constitution is under way. Chlorine gives a similar reaction. The product, crystallizing in long colorless needles, melts at 93° after recrystallization from glacial acetic acid. Analysis indicates a monochlor derivative. These bodies will be described in a later paper.

CHLORAL AND O-ANISIDINE.

Trichlorethylidenedi-o-methoxyphenamine,



With W. S. Dickson. Two molecules (12.3g) of o-anisidine were dissolved in 50cc benzene and one molecule (7.3g) of chloral were added. After warming a short time on the steam bath a separation of colorless needles occurred. These decomposed at about 215° and weighed 0.05g. On concentration of the filtrate in a dessicator a mass of fern-like crystals was obtained mixed with a thick liquid. After filtering the crystals were pressed on a porous tile. The product was white, melted at 112°-114° and weighed 9.7 grams. On recrystallizing from benzene the melting point was raised to 121°. The thick liquid finally solidified, considerably increasing the yield.

Analysis:

0.2000 gram substance gave 0.2294 gram AgCl.

1.0000 gram substance gave 0.073 gram nitrogen (Kjeldahl).

	Calculated for	Found
	$\text{C}_{16}\text{H}_{17}\text{O}_4\text{N}_2\text{Cl}_3$	
Cl	28.35	28.35
N	7.47	7.30

Trichlorethylidenedi-o-methoxyphenamine crystallizes from ligroin or benzene in magnificent rhombohedra, from one

quarter to one half inch long, always with a slight yellow color. It is easily soluble in cold benzene and carbon tetrachloride and hot glacial acetic acid. It is slightly soluble in cold ligroin and fairly soluble in hot ligroin. It crystallizes from alcohol in long slender prisms. One hundred cubic centimeters of boiling alcohol will dissolve approximately 7 grams and at 25° about 2.5 grams. It is insoluble in and unchanged by boiling water. When boiled in concentrated hydrochloric acid the odor of chloral could be detected in the vapors. A bromo derivative is readily obtained by adding bromine to a concentrated glacial acetic acid solution. The crystals occur in clusters of needles and decompose at about 230°. This compound is being further investigated.

CHLORAL AND p-ANISIDINE.

Trichlorethylidenedi-p-methoxyphenamine,



To a solution of 12.3 grams p-anisidine in 20cc benzene (a nearly saturated solution) is added 7.3 grams chloral. The solution turns to a dark red color at once, much heat is developed and a deposition of 0.22 gram small colorless crystals occurs. These decompose at about 215° as in the case with o-anisidine. After filtering, the reaction mixture is boiled 15 minutes and then allowed to stand several hours. An abundant crystalline precipitate is formed. After filtering and pressing on a clay plate, the product melted at 115° and weighed 10.5 grams. A further yield was obtained from the mother liquor. Purification was effected by using the mixed solvent, benzene and ligroin. The melting point was raised to 118°-120°.

Analysis:

0.2087 gram substance gave 0.2398 gram AgCl.

	Calculated for	Found
	$\text{C}_{16}\text{H}_{17}\text{O}_2\text{N}_2\text{Cl}_3$	
Cl	25.35	28.41

The para compound crystallizes from ligroin in brilliant scales, showing a strong pink color in the mass. It melts at 118° - 120° and decomposes at 158° . It is fairly soluble in cold benzene, alcohol and ether. It is readily soluble in glacial acetic acid, hot benzene and hot alcohol. The hot alcohol solution emits a most disagreeable odor and on spontaneous evaporation to dryness a jet black crystalline mass remains. It is very slightly soluble in cold ligroin and not readily in hot ligroin. On treatment with bromine in glacial acetic acid solution a crystalline product is obtained which blackens at about 198° . This compound will be studied further.

CHLORAL AND ANTHRANILIC ACID.

The product obtained in this case depends upon the proportions used. One molecule of chloral will condense with one or two molecules of anthranilic acid with the elimination of one molecule of water. The two products have been described by Niementowski but his method yields a mixture and we have improved upon it since we wish to make the compounds in quantity in order to study their bromo derivatives.

Trichlorethylidene-o-aminobenzoic Acid,



With W. S. Dickson. Five grams of anthranilic acid were dissolved in 40cc boiling benzene (a saturated solution) and 5.5 grams chloral in 10cc benzene were added. The weights are in the proportion of one molecule to one molecule. The mixture was boiled under a reflux condenser for three hours, filtered from a small precipitate and then cooled. A crystalline deposit, weighing 5.0 grams and melting at 148° - 151° , separated. The crystals were large elongated tables, occurring in clusters. From the filtrate was obtained 3.0 grams of material, melting at 145° - 150° . Several recrystallizations from benzene raised the melting point to 152° . Niementow-

ski and Orzechowski¹ prepare this compound without the use of any solvent. They use an excess of chloral and get several by-products. We have tried their method but have employed theoretical proportions. Even so we get the same by-products. We set the mortar in a block of ice and rapidly stirred together the previously cooled substances. The mixture liquefied and then rapidly became very hard. This product decomposed at about 127°, after two hours on ice at 124° and after three hours more at room temperature at 118°. It was rubbed up with a little water and filtered. The decomposition point rose to 135°. Now taking advantage of the marked difference in solubility in benzene of the mono- and di-compounds (not observed by Niementowski) we extracted the crystalline mass, weighing 8.2 grams, with 45cc boiling benzene. From the extract there separated a mass of colorless needles, weighing 3.7 grams and melting 149°-152°, hence nearly pure mono-compound. On evaporating the filtrate a residue was obtained, weighing 1.3 grams and melting at 160°, a good quality of the di-compound. A second extraction was made with 33cc of boiling benzene. On cooling this yielded a product weighing 0.8 gram and melting at 162°, and a residue at 157°. There still remained an insoluble residue, dark purple in color. These results are in marked contrast to those obtained by our method of boiling in benzene, for we get practically only the mono-compound and consequently a much larger yield.

Analysis:

0.2000 gram substance gave 0.3189 gram AgCl.

	Calculated for $C_9H_6O_2NCl_2$	Found
Cl	39.92	39.43

On treating a glacial acetic acid solution of this compound with bromine a bromo derivative is obtained in large quantity. On cooling a hot glacial acetic acid solution it deposits

¹(Ber. 28, 2812).

in clusters of fern-like crystals which decompose at 237°. This body is under investigation.

Trichlorethylidenedi-o-aminobenzoic Acid,



Five grams (2 molecules) anthranilic acid in 40cc boiling benzene were treated with 2.9 grams (1 molecule) chloral in 10cc benzene and boiled under a reflux condenser for three hours. During the boiling there separated 3.25 grams of the di-compound, melting at 164°-165°. On cooling a further yield of 0.6 gram was obtained. On evaporation to dryness the residue was found to weigh 4.0 grams and to melt at 157°. The pure body melts at 165°. The method of Niemcewicz¹ was tried and although found to be better than for the preparation of the mono-compound it gave a smaller yield than our method and a larger amount of unknown colored by-products.

Analysis:

0.5000 gram substance gave 0.0410 gram NH_3 (Kjeldahl).

0.2000 gram substance gave 0.2113 gram AgCl .

Calculated for		
$\text{C}_{16}\text{H}_{13}\text{O}_4\text{N}_2\text{Cl}_3$		
	Found	
N	6.96	6.76
Cl	26.11	26.10

The di-compound consists of a crystalline powder and may be purified by precipitating its ether solution with ligroin. Upon boiling eight hours with acetic anhydride and cooling, a crystalline substance deposits, melting at 183° and crystallizing from benzene in needles. This corresponds to acetyl-o-aminobenzoic acid. On treating a glacial acetic acid solution with bromine there is almost instantly obtained a heavy precipitate which after recrystallization from glacial acetic acid melts with decomposition at 236°. This behavior is surprisingly like that of the bromo derivative of the mono-anthranilic acid compound.

¹(Ber. 35, 3898).

CHLORAL AND O-TOLUIDINE

Trichlorethylidenedi-o-tolamine,

With Strowd Jordan. Chloral and o-toluidine were brought directly together in the proportion of one molecule to two molecules. No advantage was found in using benzene as a solvent. 19.3 grams chloral were added to 28 grams of o-toluidine, the mixture turned dark red and the temperature rose to 80°. After standing for some time, often over night, a quite hard crystalline cake formed. This was dissolved up in ether or successively extracted with benzene. In either case, a small residue weighing 0.7 gram remained. This was pale greenish in color and melted at 213°. The main product of the reaction was recrystallized from ether until the melting point reached 80°.

The yield was 70 per cent of the theory.

Analysis:

0.1763 gram substance gave 0.2194 gram AgCl.

0.2000 gram substance required 0.2915 gram AgNO_3 .

0.2000 gram substance required 0.2973 gram AgNO_3 .

Cl	Calculated for		Found	
	$\text{C}_{16}\text{H}_{17}\text{N}_2\text{Cl}_3$			
	30.95	30.77	30.40	30.96.

The Stepanow method¹ was employed in the second and third analyses and found to be extremely convenient. With some of our compounds we have found it impracticable on account of the deep color of the solution. We found it advisable to adopt the suggestion of Rosanoff and Hill² and filter off the silver chloride before titrating.

Trichlorethylidenedi-o-tolamine crystallizes in very long silky needles. It is not very stable in solution or when ex-

¹(Ber. 39. 4056).

²(Jr. Am. Chem. Soc., 29, 269).

posed to the light. It is decomposed by water into chloral and o-toluidine. It is soluble in cold alcohol, ether, acetone, chloroform, carbon tetrachloride, carbon disulphide and glacial acetic acid. It is soluble in hot ligroin, benzene and methyl alcohol. The pure substance melts at 80° and will melt repeatedly at that temperature. A bromo derivative is readily obtained in glacial acetic acid solution. It forms silvery white plates which melt with decomposition in the neighborhood of 268°.

PHYSIOLOGICAL ACTION.

We were led to a study of the physiological action of the trichlorethylidenedi-o-tolamine by an accidental observation. Mr. Jordan unintentionally got a small quantity in his mouth and within a few hours there followed a marked physiological action. A preliminary test has been made upon two rabbits. Dr. William DeB. MacNider of this University kindly carried out the test for us in the pharmacological laboratory of the University of Chicago. A 5 per cent dilute alcoholic solution was employed. This was first used in 10cc doses, intravenously. It produced at first a slow heart action accompanied by a slight fall in blood pressure. Following this initial change the respirations became accelerated, the heart action fast and the fall in blood pressure much more pronounced. Doses of 25cc given by the stomach caused the animal to become drowsy, inactive and imperfectly responsive to stimuli. The respirations were accelerated. One rabbit returned to a normal condition in six hours. The other animal, receiving the drug by the stomach, died apparently from respiratory failure. A more complete study is under way upon a large number of rabbits. This study will be extended to other diphenamine derivatives of chloral.

Chapel Hill, N. C.

Oct. 16. 1907.

RECENT CHANGES IN GOLD MINING IN NORTH CAROLINA THAT HAVE FAVORABLY AFFECTED THIS INDUSTRY

BY JOSEPH HYDE PRATT AND A. A. STEEL *

Before taking up an account of the changes that have been recently introduced in gold mining in North Carolina, it may be of interest to mention some of the causes for failure in the profitable mining of gold in this State, as the changes to be described have to some extent at least modified and lessened the chances for failure.

Many of the causes of failure in North Carolina gold mining can be traced to a lack of adequate capital, which prevents mining from being conducted in the most economic manner. One of the most noticeable of these is the tendency to sink the shafts but 15 to 30 feet before driving a new level and then stoping out a small block of ground instead of having the levels from 75 to 100 feet apart. Since a ton of ore removed in driving the level even in a wide vein will cost fully twice as much as a ton of ore in stoping, it is obviously more economical to have as few levels as possible. If it becomes difficult to make the raises more than 100 feet and is expensive to get men and timbers into much higher stopes. Therefore, the levels should not be over 100 feet apart. In a narrow vein where much waste could be left in a stope, the economy is greater. Somewhat similar to this is the habit of sinking a number of shafts close together instead of only one or two on a vein. This is not so bad for working ore

* Published with the permission of the State Geologist of North Carolina

near the surface, but becomes very expensive as the mine gets deeper, especially when hoisting machinery is required on each shaft. This is partially explained by the fact that many of the old mines have been worked at very irregular intervals and the old shafts have become caved in during the period of idleness.

Even those mines having capital are often badly managed. They frequently put in machinery of unnecessarily large capacity, not realizing that a very small engine and bucket can easily get out 10 or 15 tons of ore per day and keep a five stamp mill busy. There are many little mines that could pay a profit under careful management with five stamps and running only one shift; but some of them have engines big enough to hoist four times as much ore. Since the engineer and top men must be there all the time, there is no economy in operation but may even be a loss, since the engine cannot work steadily and fuel is wasted keeping up a big fire; and of course, the first cost is greater. If the mine ever gets much too big for the small engine, it can be used in prospecting or underground work.

A great many shafts are much too big. It is not uncommon to see a little bucket, 30 inches across dangling in the middle of a hoisting compartment 6 feet square in the clear. It is considerably cheaper to sink a shaft with compartments only 4 feet square in the clear and when the hoisting compartment is smoothly lined with plank (to assist ventilation), or fitted with guides, it has just as great a capacity — usually more than enough for the output of the mine. If necessary, the hoisting capacity of a shaft may be greatly increased at any time by putting in a tall bucket, or better a self-dumping skip and high speed engine. The ladder and pipe compartment is often as big as 6 by 8 feet. Since the cheaper and better direct acting steam pump would now be placed in a shaft, instead of the clumsy and bulky Cornish pump, the water, steam and compressed air pipes take up very little room. It is now customary to put in slanting ladders between landings some distance apart. They can almost as well be a little

steeper and shorter and go in a smaller space. The men will always ride up in a bucket, fitted with a crosshead running in proper guides or running in a closely planked compartment if the shaft is crooked. Therefore, the ladderway is an emergency exit only and a good, continuous vertical ladder securely fastened against one wall of the compartment is all that is needed, and the compartment for ladder and pipes may seldom need be over 3 by 4 feet. The two compartments and the division between them then need be only 4 by 8 or 3½ by 7 feet inside. Besides being much more cheaply and rapidly sunk, the small shaft need not be so heavily timbered, since the shorter timbers are stronger and the earth pressure tends to arch around the shaft instead of coming full upon the timbers. On the other hand, the first 6 by 10 feet (8½ by 12½ feet outside timbers) shaft at the Montgomery Mine, at Candor, Montgomery County, became useless after about 5 years from the buckling of the timbers, although splendidly timbered with 12 by 12 inch oak sets, which showed no signs of decay.

There is, of course, very seldom any need for more than one hoisting compartment, since the saving in power will only pay for the greater expense of engine and shaft when a large amount of ore is to be hoisted from considerable depth. When a single large skip will handle all the ore, there is no need of putting in another to remain idle half the time.

Timber framing for shafts and tunnel sets is often unnecessarily complicated and the carpenter must waste much time chiselling, when simple notches laid off with a square and cut by saws are often stronger and always more easily made.

The most disastrous error is usually great haste in putting in a mill or smelter. It seems that the first thing that many miners think of after finding a little good ore is to stop work in the mine and put in a mill; so there are mills which have been able to run less than a month before the mine was exhausted. There is usually a neighboring mill to which the ore might as well have been hauled. It is seldom that tests are made to tell what sort of a mill and treatment is adapted

to the ore. Unless the ore body is large, no mill should be installed until the changed ore below the water level has been tested.

In North Carolina there seem to be only a few miners who deceive themselves by assaying the rich streak and assuming that the entire streak will be equally as good. The general principles of sampling the entire body seem to be well understood, although it is not always done as accurately as it should be.

Even when good ore occurs in paying quantities the miner frequently builds a mill that is too large; For there is only a little extra expense in increasing the size of the mill after it has been running awhile instead of building a large mill all at once. So there is little excuse for assuming the greater risk of a large mill. There is less loss of gold in adjusting a small mill.

One agreeable exception to the practice of building a mill before the mine is sufficiently developed is seen in the work of the Whitney Company, who have carefully tested and explored a number of mines. Many of the options were given up of course. At the old McMakin Mine at Gold Hill, as explorations proved the value of the mine, the contemplated scale of working was gradually increased. When the small shafts of the upper levels were deepened, the lower parts were made large enough for balanced hoisting and the small part will be enlarged later. In the meantime most careful sampling and assaying was done and when enough ore had been blocked out, careful mill tests were made chiefly upon the material obtained from drifts. In this way a total of 4,950 tons of ore was run through the little mill on the ground; careful records of everything gave an average recovery of \$4.52 of gold on the plates and only \$0.34 per ton as a concentrate worth but \$5.03 per ton and \$0.83 per ton in the tailings. These tests made clear that the most economical method is simple amalgamation, giving a saving of about 80 per cent of the gold, with no attempt to concentrate and treat the concentrates.

The two main shafts are down 800 feet and another is 400 feet deep, with the levels averaging over 700 feet long. This work shows a vein averaging 14 feet wide and gives a million and a half tons of ore blocked out ready to stope, and which will yield \$2.50 per ton by amalgamation. They have accordingly planned a mill large enough to treat 1,000 tons of ore per day, making the estimated total cost of mining, milling and transporting the ore only \$1.48 per ton. They are now waiting for the completion of their water-power plant before building the mill and since they have sufficient ore blocked out, the mine has been idle and full of water since the spring of 1905. The intention is to keep a reserve of 500,000 tons of ore in advance of the stoping.

The Bonnie Doone, or Old Smart Mine, has also been properly developed by Mr. J. C. Bates, a former owner of the Howie Mine. The old 80 foot shaft has been deepened to 200 feet, with levels 125 feet long at 60 feet, 100 feet at 120 feet, 160 feet at 186 feet. The ore obtained from these workings is now piled in a large dump estimated to contain 3,000 tons. And before the mill was planned, this was carefully sampled by a competent mining engineer, who dug deep trenches across it and found it to average \$15.00 per ton. Of course a great deal of the same quality of ore has been blocked out in the mine. There are about 500 tons in another dump of material which came from work in the walls and is chiefly slate but contains a few of the veinlets and masses of milky quartz, and is said to assay about \$1.50 per ton. It has been kept out of the good ore at only a nominal expense. The mill has not been built on account of the continued sickness of the owner, so there is no machinery at the mine except the sufficiently large prospecting hoist.

As an example of a mill too large for the development may be mentioned the Reimer Mine, near Salisbury. Here a 20 stamp mill with chlorination failed simply because no ore at all had been blocked out and it could not be mined rapidly enough to keep the mill going. An examination of the mine by the late Mr. Parker, mining engineer for the Whitney

Company, showed a remarkably continuous vein, averaging $3\frac{1}{2}$ feet wide and carrying \$7.50 in gold.

Mr. Parker planned to develop the mine so that it might easily yield 50 tons per day, so the total cost of mining and treating the ore would be about \$4.50 per ton, which includes depreciation, etc.

The general custom of having no reserves of ore blocked out prevents conservative mining men from investing in them, since there is no way of determining the value of the vein unless it is opened up. It would be much better to spend the cost of a premature mill in developing ore so that there would be no difficulty in securing capital or selling the mine to advantage.

It is also quite customary to extract all of the ore by underhand stoping. This becomes very expensive when the vein is so narrow that some of the wall-rock must be broken to make room, or when the vein contains much barren rock. All of this waste material must then be hoisted to the surface and much of it becomes mixed with the ore in the bins and chutes. If the stopes are mined upward or overhand, all the waste can be left in them supported on a single line of stulls over the drift. This often affords a scaffold for the men and so saves the great expense of putting in many stulls. In addition a large block of filling will serve as a pillar to hold the walls apart so no ore need be left in the mine. One excellent mine superintendent said that the reason for this was the fact that most of the miners are more properly farmers and cannot drill holes upwards. They do not work steadily enough to warrant an attempt to teach them how, even though skilled men prefer to drill "uppers." This objection can be overcome in those mines having air drills for driving levels by installing a few of the blockholing or air hammer drills which may be held in one hand and, besides being much quicker, can be worked in stopes too narrow for hammering by hand. So far there seems to be none of these machines in North Carolina, although they are becoming standard in the west.

When the mines yield rich ore in narrow streaks, it should be hand-picked before going to the mill. For this purpose the Miami Mining Company have installed at the Phoenix Mine, near Concord, Cabarrus County, an ore picker. The ore is sorted into coarse and medium material by passing through a trommel, where it is also washed by a spray pipe. It then passes over a couple of belts 30 inches wide and 30 feet long. A number of boys sit along these belts and pick out the waste, which is removed by another belt, while the good ore passes direct to a Dodge crusher. The dirt and fine ore removed by the water is raised by a sand pump directly to the battery. These machines would not pay at a small mine where an arrangement like that at the Hercules Mine at Cid, Davidson County, is better. Here the ore is dumped from the skip on to a slightly elevated platform, where it is washed by a stream of water from a hose and the waste thrown into a car standing near, as the good ore is shovelled into a car for taking it to the mill.

Since the publication of Bulletins Nos. 3 and 10 of the North Carolina Geological Survey, there have been a number of changes in mining practiced in the State, which, given in the order of their probable importance, are:

1. The application of machines of the old log washer type to separate gold from saprolites as is now being practiced at the Shuford, Empire, Beaver Dam, Troy, Sawyer and other mines.
2. The introduction of square set timbering in the extraction of soft, deep ore bodies, which is now being practiced at the Union Copper Mine at Gold Hill.
3. The introduction of the cyanide process for treating certain sulphuret ores, which has been practiced on the tailings from the Iola, Montgomery and Howie mines.
4. The introduction of self-dumping skips, picking belts etc.

LOG WASHERS

Perhaps the most important change to be noted in gold mining practice in North Carolina is the introduction of log washers in treating many of the saprolitic ores that are found quite abundantly throughout many portions of the State. The old principle of the log washer cannot be patented, but the machines that are now being used, known as modern pulverizing concentrating machines, possess many mechanical improvements that adapted them to the work that they are called upon to do.

Each separate unit of these machines consists of two improved log washers running at high enough speed to readily disintegrate the soft material and so mix the clay into a fine pulp with water that the gold can readily settle to the bottom. Each machine is essentially a long trough or boiler plate containing a revolving cylinder fitted with heavy white iron arms set spirally so that the ore, while being hammered fine, is gradually worked to the discharge end. At the end of the first washer, the larger, hard and nearly barren quartz stones are removed by a revolving screen and belt conveyor, this being done to save wear and power in the second washer, where the gravel is still further reduced in size and more gold settles out. The gravel that remains after passing the second washer is removed by a finer screen and the chief pulp, free from stones, passes from the riffled sluices about three feet wide and of varying lengths, which contains mercury to amalgamate and save any free gold that does not settle in the machine.

The steel troughs are about 2 feet wide by $2\frac{1}{2}$ feet deep, the first being 18 feet long and the second 12 feet, with a semicircular bottom and a flat wood top. The revolving cylinder is made of an 8-inch steam pipe carried upon a heavy steel shaft, passing through stuffing boxes at the ends of the trough. Wrought iron bars reach through this pipe crosswise and project about 3 inches on each side to form legs to which $8\frac{1}{2}$ inch cast iron arms are bolted to take all the wear. There is about 4 inch clearance between these arms and the

bottom of the troughs, which allows the formation of a bed of stones, which reduces the wear on the bottom and helps save the gold. This bed of stones is of course more or less shaken up by blows from the large fragments of quartz and by the revolving arms, thus permitting the gold to settle through as in panning. The constant striking of the paddles against the surface of the water will also weight and sink some of the float gold. The discharge end of the machine is set 6 inches higher than the feed end so that the gold, once down amongst the pebbles of the bed, is not apt to be pushed out.

Riffles of the sluices are made by boring inclined auger holes in the planks laid lengthwise in the cement-lined sluice boxes. Since all the coarse gravel has been screened out, there is little wear upon the riffles and the fall and quantity of water are less than in the regular sluice for hydraulic mining. In cleaning up, the planks are lifted up and turned over and the gravel and mercury washed to the end of the sluice where quicksilver and amalgam are washed out in hand pans. When through cleaning up, the planks are simply replaced and the riffles filled with mercury and the machine started again.

In cleaning the washers, which is usually done twice a week the machines are stopped and all the gravel within washed out with a hose through an opening in the bottom. This gravel is then panned by hand and the gold amalgamated. Any nuggets that occur in the rock are pounded free from quartz and are then also amalgamated.

The amalgam from all sources is strained out of the quicksilver and then retorted and the bullion sold.

The chief wear on the machine is the arms, which under certain conditions, as on the sharp ore at the Shuford mine, only last six weeks. They can, however, be readily made at any foundry.

It is recommended by the maker that the first washer be driven at 150 to 250 revolutions per minute and that the second one at 250 to 350 per minute and that for a capacity of 10 tons

per hour, each machine be given 72 gallons of water per minute. This will then at times require 25 H P. for a complete unit of two washers and trommels. These factors will vary greatly with the character of the ore. Since the power, and therefore the wear, will increase even more rapidly than the square of the speed, this should be kept low. In the absence of any coarse stones, there is also danger that the pulp may be too greatly agitated to allow the settling of the gold. On the other hand, the speed and work must be sufficient to grind up the ore. If there is too little water, the clay paste may not allow the gold to settle. If there is too much, there is a danger of the gold being washed out. While a large capacity is of advantage and desirable, still it will mean danger of insufficient grinding, too thick pulping, or too strong a flowing of water. A great deal of skill and patience is, therefore, required in adjusting these fixtures, but when once adjusted, they will work satisfactorily. It is to be recommended that a first unit be installed and run over several months at various speeds, capacities and amounts of water and the machine should be given plenty of time after each change of condition to adjust itself. Also, careful tests of the ore and tailings should be made between times. The capacity and speed should first be adjusted until the best result is given in reducing the amount of gold left in the tailings so combined that it will not pan. The pulp should of course be kept at a reasonable consistency throughout the changes and the amount of water finally adjusted so that the tailings will show a minimum of free gold in the pan.

These machines are made in Knoxville, Tenn., and are handled by Geo. L. Erdman, of Asheville, N. C. One of the first of these machines was installed at the Shuford Mine, owned by the Catawba Gold Mining Company, and situated about three-quarters of a mile north of the post-office of Edith, about 5 miles south-east of Catawba Station on the Southern Railway. They have a plant of 4 double units. The Company are operating on a tract of land containing a gold-bearing zone said to be 2 miles long and 600 feet wide.

This will all pan gold at the surface and has been tested by bored holes 30 to 50 feet deep to water level and by one old shaft 115 feet deep. This zone is filled with small quartz seams from a line to occasionally several inches thick and having all possible strikes and dips and seldom more than two feet apart in every direction. The country rock varies from schist to gneiss and is generally heavily stained by iron oxide and thoroughly decomposed, except for a few, bold outcropping hard masses. The quartz is usually thoroughly honey-combed and broken into soft, angular fragments. Except at the surface, most of the gold is in these quartz streaks, but the hard and solid portions of them seldom have much value. At the present time the entire mass is being mined by means of an irregular pit which was, in the summer of 1906, 90 feet deep and 250 to 300 feet across at the top. The material at the bottom is just as soft and decomposed as at the top and the ore is loosed by black powder and shovelled by hand into cars containing a cubic yard. The cars are hoisted up a steep incline and automatically dumped over a grizzly of light steel rails. The fines are washed through the grizzly by jets of water, the soft large lumps being crushed and knocked through by means of a pick. In 18 months operation only a few tons of large, hard lumps have thus far been thrown out. The material is then washed down a trough about 50 feet long, thus becoming pretty uniformly mixed before being divided among the washers. At this mine the machines are run at only 150 revolutions per minute. They were tried at a lower speed, but there was trouble with the gold sticking to clay balls. The machine used about 150 gallons of water to the minute and the whole plant is run by a 35 horsepower engine which, when the three units are running, is probably overloaded. The tailings, when tested, usually pan nothing at all, but assay a few cents, due to gold included in the sand. While this loss could be reduced by speeding up the second washer to grind the sand finer and trusting to the riffles to save what little additional free gold would not then settle in the machine, it

is doubtful whether with the present small plant and so vast a quantity of ore controlled by the Company such refinements are advisable, since they would probably reduce the capacity of the plant. It is estimated that the present cost of treatment is 22 cents per cubic yard loose measure with a recovery of between 50 cents and \$1.00 per cubic yard.

A great deal of the success of the Catawba Gold Mining Company is due to its conservative policy and the skill with which the whole mining and milling operation has been conducted.

The next machine to be placed in operation was at the old Laflin Mine, near Cox, Randolph County, about 4 miles east of Cid Station on the Thompsonville and Glen Anna Railway. The Empire Mining Company own a tract of land which contains argillaceous slates containing two gold-bearing zones, 200 feet wide by $\frac{1}{2}$ mile long, the northwest zone being along the south side of a hard quartz and siliceous slate vein. The early work on this property was done at the northeast end of the northwest zone where there are several large pits, some 50 feet deep. The entire surface was tested by pan assays (weighing the amount of gold from known weighed amounts of ore) and a number of trenches were dug across the better portions of the zone. The results of this test led the Company to instal their experimental plant on the gentle slope to another stream near the southwest end of the northwest zone. At the other end the slates are still soft at a depth of 50 feet, but here they were found to be quite solid and tough within 6 or 7 feet of the surface, though drill holes are said to have proved that the rock is again soft below a 5 or 6 foot shell of hard material. The dip at this end is only 15 or 20 degrees instead of being nearly vertical as at the other. This tough slate is thoroughly oxidized and shows a very uniform distribution of wheat-like grains of limonite, formed from pyrite, which lie along the cleavage planes of the slate and all the gold occurs in them.

This small branch has a steep fall for 2 miles to the Yadkin River and for the experimental plant water is returned

from a small settling pond nearby. In order to get sufficient fall for the head and tail sluices, the machines are put pretty high up on the hill so that a fat incline has been put in with dumping arrangements, etc. similarly as at the Shuford Mine. The ore is broken up by hand into about 3 inch cubes and when not hard, there is some tendency for it to stick in the grizzly crusher owing to the large percentage of clay, which is often moist. The first machine is run as high as 250 revolutions per minute on hard rock, but was found to give best results on average partly decomposed slates at 175 revolutions per minute. As there is no hard quartz in this ore, there is no need of an intermediate trommel. The second machine is operated at only 90 revolutions per minute and saves most of the gold, which is very fine. The trommel which follows this washer removes practically nothing but fragments of tree roots, which shows that everything is ground below 4-mesh. The riffles are 64 feet long, but very little gold is found below the first 20 feet. With this soft, clayey ore the capacity is about 8 tons per hour and 110 gallons of water per minute are required. In the summer of 1906 the machine had hardly passed the experimental stage, but the tailings almost never showed any free gold and assays of carefully taken samples showed a recovery of 90 per cent of the soft material and 80 per cent on the hard.

A few modifications of the machine have been made by Mr. O. K. McCutcheon, Superintendent of the Empire Company, by introducing an improved stuffing box and valve for the clean-up openings and in the second washer installing a plate 9 inches wide and one inch above the center of the bottom with cross-lots $\frac{1}{2}$ inch by 5 inches. This false bottom is curled up at the discharge end and serves as a riffle plate, thus considerably increasing the recovery of very fine gold.

One double unit of these machines was being worked on the property of the Troy Mining Co., 7 miles north of Troy, Montgomery County. There are some old shafts, but the two main workings are based upon recent discoveries. By test pits and panning it seems there are two parallel zones of

slate bearing gold. Open cut No. 1 shows white and pink, clay-like slates with iron stains and abundant limonite cubes and seams. The direction of the slates is N. 45° E. and part of the material seems to represent thoroughly decomposed, sheeted, coarse grained porphyry so that the deposit is probably on a contact. The values are not uniform and at a depth of about 12 ft. the deposit seems to be about 20 ft. wide, 50 ft. long and the upper part of a rounded lens, richest in the center, where a 25 ft. shaft is said to have produced \$30.00 ore. To develop deeper, a shaft was sunk in the hanging wall. At a depth of 70 feet, it was stopped just as it began to cut light-colored, sericitic schists, carrying pyrite.

The material from open cut No. 1 was all conveyed by a sluice to the mill, a short distance away. Although a good deal of gold was saved, the tailings ran \$3.00 a ton and tests were stopped.

Open cut No. 2 was made by recent unsuccessful hydraulic mining. It was, at the time of the visit, 200 feet long, 20 to 24 feet wide and 2 to 10 feet deep. This zone pans quite uniformly 18 to 20 feet wide in the cut and in cross trenches beyond the end of it. No assays of average samples have been made. There is a barren, white quartz vein, with some large quartz crystals, along part of one side of the zone and most of the material seems to have been more or less siliceous sericite schist, now thoroughly decomposed to purple clay or fine sand. At the time of the visit, 100 tons were being hauled over muddy roads to the mill about a quarter of a mile away, to make a test run.

The machines were found to give a little less free gold in the tailings as the speed was reduced, and at the time of the visit, both sections were being run at only 60 R.P.M. The rate of feeding is very low, apparently only 2 tons per hour, and the amount of water is very large, apparently about 150 gallons per minute. As there was no hard pebbles or other material in the ore to form a bed in the machine, it is probable that most of the gold was washed out. Even at this low rate of speed the coarsest tailings were very fine

particles of sand. Samples of the tailings included only the coarser, rapidly settling parts, so that the assays made were probably too high. It may be that the slower speed simply decreases the pan assay of the tailings by not freeing such a large percentage of gold which remains included in the larger grains.

The most apparent recommendation would be to put McCutcheon riffles in the bottom of the machine, run the first machine faster than the second and greatly increase the percentage of ore fed to machine as compared with the amount of water used. No samples of the ore had been taken so the tests are not conclusive.

The latest reports are that the tailings from open cut No. 2 also assayed \$3.00 to \$4.00 per ton; that the washers are abandoned and that a 50 ton cyanide mill will be erected. It is also said that some good ore was struck below a quartz vein in a 17 ft. shaft, sunk in open cut No. 2. It is probably well to abandon the washers here because the thoroughly decomposed soil gets very hard not far from the surface, and the water level will be less than 30 feet below the highest part of the ore zone now exposed. Therefore the available tonnage of decomposed material is rather small. A shaft on a third vein, just below the creek bed, shows hard silicified sericite slates, with much pyrites but no visible copper or other minerals which would interfere with the cyanide plant adapted for handling slimes.

Machines have also been installed at the old Sawyer Mine in Randolph County 5 miles west of Sophia and about 14 miles from High Point. This property has been worked off and on for many years, but has failed because the gold could not be saved by a stamp mill and plates. The machine will first treat the soil and very soft outcrops and then the hard rock, which does not slack by itself will be crushed fine by rolls and the machine used simply as a panning device. This will be a new and novel use for this machine and the results will be watched with interest.

The McCutcheon modification of the Modern Pulverizing and Concentrating machine is being installed at the old Mer-

rill Mine on Carraway Creek 3 miles west of Sophia. The old workings are said to show a zone 1-2 mile long which is composed principally of clay to a depth of 50 or 60 feet. There are eight long cross-cut trenches and many test pits have been made which are said to have given ore running from \$1.50 to \$1.90 per ton.

Near Newton, Catawba County, one of the machines is being installed to work a property said to be similar to the Shuford Mine in the same county.

From information obtained by observation in the field and tests in the laboratory, it would seem that this Modern Pulverizing and Concentrating machine is adapted for certain ores such as those of the Shuford Mine and that with certain modifications as have been worked out by Mr. McCutcheon, the machine can be adapted to still other ores. It is necessary, however, to make a careful study of the ore and to adjust the machine to each particular ore before it can be determined whether or not the machine will save the gold; and a machine should not be accepted or discarded until the ore has been thoroughly tested to ascertain whether or not the machine can be adapted to that particular ore.

SQUARE SETS.

The second change in mining practice of great importance to the gold mining industry in North Carolina is the introduction of square set timbering in the extraction of soft deep ore bodies. This method was introduced by Mr. H. L. Griswold, superintendent of the Union Copper Company's mine at Gold Hill, N. C. In former mining the old stopes were held open by miscellaneous timbering such as stulls, lock sets and truss sets. Such methods were not satisfactory and prevented the stoping of the ore in the most economical manner. By the introduction of the western square set method of timbering, the stoping of the ore is being done safely, completely and economically. The sets are made of 8 x 8 inch sawed oak and the mine carpenter can usually easily frame enough timber for this work in about one-eighth of his time. The

sets are 6 ft. 3 inches high in the clear and 5 feet across in the clear. The posts are, therefore, 6 ft. 3 inches long between the shoulders and have a 5 x 5 inch tenon $1\frac{1}{2}$ inches long at each end; the caps are 5 ft. 3 inches between shoulders and have a 5x5 inch tenon $2\frac{1}{2}$ inches long at each end; the ties are 5 feet between shoulders and have a tenon 5x8 inches and $1\frac{1}{2}$ inches long at each end.

The size of the timbers will of course vary with the weight to be sustained. This style and proportions of framing are very good for oak timbers; but for pine, which crushes so easily across the grain, it is better to have the ends of the post tenons to touch each other. The light timbers are of course cheaper and much more easily handled. As the stopes get large, they are more or less completely filled with waste rock which is usually obtained in mining and would otherwise have to be hoisted out in working the usually underhand stopes. This filling also holds the posts in position and helps to prevent them from buckling or "jack-knifing" if any one timber yields, which might otherwise endanger the whole system. Since most of the pressure is downward, as soon as the ore is blasted away to make room for a new set, all the sets below are relieved and tend to come back to their original position. Thus, even light timbers will hold very well if the stope is worked rapidly enough.

In the Union Copper mine the square sets were founded upon a platform built upon the old solid looking truss sets. As soon as a heavy load came upon them the trusses buckled sidewise and everything caved in. A new foundation was then made upon reinforced stulls and there has been no trouble since. Mr. Griswold is starting a new lot of square sets in a large open chamber just above the fourth level and he will thus be able to work out easily all the ore left above, especially a big pillar that remains between the first and second levels.

A new set can be added in any position at any time without disturbing the adjoining timbers and the old timbers can easily be supported by temporary props while making room

for an additional set. When the old timbers have been replaced the entire flooring of sets is easily put in as the ore is removed; a temporary plank covering may be placed across the old timbers to protect the men from falling rocks. Temporary plank floors are placed upon the sets for the men to stand upon and, as the system becomes higher, chutes and mill holes are put in to conduct the ore to the car on the track below. Any waste rock mined is merely dumped in and around the lower sets.

There has been little or no trouble introducing the square set method of timbering and at the Union Copper Mine the work is done under the immediate supervision of Mr. Hedrick, a skilfull North Carolina shift boss who has had no previous experience with square sets. Some of the miners, especially negroes, when first stoping by means of square set timbering are a little nervous because they are so close to the roof that they can see how loose the rocks are; but they soon realize that they can pick down the loose rock or prop it up and, therefore, are safer than when they are so far away that they cannot tell at what moment the rock may fall upon them. Also when working at the bottom of a high, underhand stope, a blow from even a small rock would be dangerous.

CYANIDE PLANTS.

The introduction of the cyanide process for treating certain sulphuret ores is a third change in mining practice in the State that has added considerable to the production of gold. One of the most successful cyanide plants was the one erected to work the tailings of the Howie mine, near Waxhaw, Union County. This mine is in a zone of hard, siliceous slates, carrying chimney-like bodies of pretty high grade ore. The gold is all free but so finely disseminated that the high grade ore which is a laminated or schistose quartz has merely a golden sheen. A great deal of this escaped amalgamation although enough was saved to pay well. These old tailings, which are rumored to have been worth 5 or 6 dollars a ton, soften

somewhat upon exposure to the weather so that the recovery by cyanide was very good.

The old cyanide plant had four iron tanks $5\frac{1}{2}$ feet deep and 30 feet in diameter and supposedly the necessary other tanks and apparatus. When the tailings were exhausted the mine was sold to the Colossus Mining Company, a London corporation, which proposed to put in an immense plant to treat the entire zone. This zone had previously been cross cut by two trenches somewhat over 20 feet deep, but it was never properly sampled, for although there are many fairly rich streaks, the general average value is only 40 to 50 cents a ton. The tanks of the old mill were made a part of the new big mill, so the original arrangement of this successful plant could not be learned and also no one could be found to give information about the successful treatment. There is now a Ledgerwood cableway for economical handling of excavated rock. This dumps the skips of rock upon the feeding platform of a very large gyratory crusher discharging into a trommel. The coarse rock from the trommel goes through a smaller gyratory crusher into the bin containing the finer rock. From this bin it is hoisted to a long, rotating cylinder dryer discharging to the first of a pair of Allis rolls working in series with necessary screens and elevators. The fine material from these rolls is divided among three ball mills of peculiar design. They have a vertical axis bearing arms which push a number of six inch iron balls around a horizontal runway.

There are at present no screens on these, and the product contains a good deal of troublesome dust or slimes, and some sand too coarse for successful cyaniding. From the ball mills a fine set of conveyors carry the dry material to any one of the leaching tanks. There are six tanks $5\frac{1}{2}$ feet deep and 40 feet in diameter, and four tanks $5\frac{1}{2}$ feet deep by 30 feet in diameter, all in the open air; and the necessary solution, gold and slump tanks. The mill is very badly designed since the rolls have scarcely capacity for 75 tons per day and the ball mills were so overworked that much coarse sand passed

through them. On the other hand, the crushers, elevators, etc., have a capacity fully four times as great. The mill has been used by the present management in making cyanide tests upon the rich ore remaining in the chimneys. Even when crushed very fine this fresh unaltered ore can be leached for a week without apparently giving up more than half its gold, thus this cyanide plant cannot be used for this ore.

At present the most productive cyanide plant in this State is the one at the Iola Mine, near Candor, Montgomery County. The ore, coming from a pretty sharply defined vein, is either a hard, glassy, white quartz with traces of unreplaced slate, carrying coarse gold in octahedral crystals; or soft sugary, white quartz generally richer but not showing visible gold. This "sugar quartz" has lately been running from \$14.00 to \$20.00 per ton. It is crushed in a dilapidated 20 stamp mill where the coarse gold and much of the fine gold is amalgamated as usual. The tailings are elevated and are run to the various settling tanks or "sand boats," 3 feet wide at one end, 5 feet at the other, 12 feet long and $3\frac{1}{2}$ feet deep, having at the small end a wooden lattice on the inner side of which a canvass curtain may be rolled up from the bottom. When the thin tailings run into this the sand settles out and the fine part or slimes flow into the slime tanks. As the sand accumulates the curtain is unrolled so that the overflow is just above the level of the top of the sand. The other two sand boats, just above the tanks, are plain boxes 6 feet by $3\frac{1}{2}$ by 15 feet. One end is bored full of holes to let out the slimes. These are plugged as the level of the sand reaches them.

The wet sand from these boats is shovelled or wheeled into whichever of the sand tanks may be empty. This shovelling thoroughly breaks up any water tight layers of slime which may have formed when the mill was shut down for a short time, and the thin pulp remaining below the overflow has a chance to settle in a layer on top of the sand. It also supplies the needed oxygen to aid the cyanide in dissolving the gold. The sand tanks were made locally of yellow pine and

are 4 feet deep and 20 feet in diameter with the usual cocoa matting filter in the bottom. When filled to convenient height, they hold 40 tons of sand. A solution containing 1.4 pounds of potassium cyanide per ton of water is pumped upon this and drained off through the filter; this solution is kept circulating as rapidly as possible, keeping the sand always covered, for three or four days until the sand must be removed to make room for another batch. Then the solution is allowed to drain off, after which a little water is added to displace what solution remains in the damp sand. The sand is then washed out by a stream of water from a hose through an opening in the bottom of the tank into a trough or launder, to a settling pond where the sand settles out and the water collects to be pumped back again.

The slimes flow from the sand boats to one of the three agitation tanks 10 feet deep and 20 feet in diameter. Near the bottom of each of these is a slowly revolving paddle consisting of four well braced oak arms carrying pins. Some of the surplus water is drained off and a solution carrying 1 pound of potassium cyanide per ton of water (0.05%) is added. The agitation continues while the solution and slimes are drawn off at the bottom to a 4-inch centrifugal pump, thus thoroughly aerating and mixing it. This process continues until the tank is needed for more slimes. The solution is then pumped into one of the settling tanks 14x18 feet at a little lower level. Here the solid matter slowly settles out and the clear solution is drawn off. Sometimes the slimes are returned for a treatment with a second solution until they are finally sluiced out to waste. The solution from the sand tank, which now contains the gold, is passed directly to the zinc boxes; these have six compartments, 2x2x2 feet, with a side trough and a diaphragm for circulating the solution. This arrangement allows any one box to be emptied and cleaned while the solution circulates through the others.

From the zinc boxes the solution flows to the sump tank, 10x20 feet. Here more potassium cyanide is added to replace what has been consumed until the solution reaches the right

strength. This sump tank thus serves for a solution tank, from which the solution is raised by a small centrifugal pump to the sand leaching tanks. Most other mills have a small extra tank at the highest level in which the solution is made up and from which it flows by gravity to the sand tanks.

The clear solution from the slime settling tank is stored in the tank 24x8 feet. From this it flows through an eight compartment zinc box like the other one and to the sump and weak solution tank.

In the zinc boxes zinc from a mass of fine zinc shavings enters the solution in place of the gold which is precipitated as a black coating upon the zinc. Each month the zinc in the boxes is sifted and the fine stuff saved, and the coarse stuff returned to the box. The deficiency of coarse zinc in the first box is made up by taking some of it from the second, which is in turn filled from the third and so on. All the fresh zinc required is added to the last compartment, and, since much of the gold sticks to the zinc until it is all dissolved, most of the gold slimes are recovered from the first compartment where precipitation is also most active, as the solution passing through it contains the largest percentage of gold.

The gold slimes, or finely divided gold, containing small scraps of zinc, is melted in a graphite crucible to which a little nitre is added to oxidize the zinc and cause it to unite with the borax used as a flux. The melted gold is cast into bricks and sent to the mint.

All the tanks are in the open air. The pipes are wrapped to prevent freezing, and there is no trouble except that heavy rains increase the amount of solution which must be wasted and so cause a greater loss of potassium cyanide. The pumps, and the engine for driving them and the agitators, are housed in. In the same building is the room containing the zinc boxes and furnace for melting the bullion. About 4-10 of a pound of potassium cyanide is consumed per ton of ore. In the ore are no copper minerals or similar substances to consume cyanide.

Eight pounds of lime are added to each ton of tailings on its way to the cyanide plant. This is to cause the slimes to settle more readily and neutralize any acid which may be formed from the pyrites in the ore, and which would otherwise consume cyanide. The chief loss of cyanide is, therefore, in the solution that is wasted with the wet slimes.

There is required one solution man at \$1.50 a day for each shift. If one-half of the steam used at the mill is charged to the cyanide part, the total cost exclusive of interest and depreciation is \$0.90 per ton. The tailings from the cyanide plant contain about \$1.00 per ton of gold. Since the sands from the mill had been carrying \$4.86 per ton, there is a handsome profit in the cyanide plant—about \$2.90 per ton treated. The cost of the plant was from \$10,000 to \$12,000. The loss in the tailings could be reduced by a longer treatment of the sands and the intention is to add two more sand leaching tanks for this purpose.*

At the Montgomery mine, which adjoins the Iola, there is another cyanide plant for treating tailings from a 10 stamp mill. All of the tanks are square. The stream of tailings is first separated into slimes and sands in a pointed box. Near the bottom of this box is a pipe out of which the coarse sand, which settles most rapidly, flows to the settling tanks, over the sand tank, while the slimes overflow at the top opposite the inlet. The slimes are not treated and the sand treatment does not differ essentially from that at Iola. The mine was shut down at the time of the visit so no data as to the cyanide treatment could be obtained. From the relatively greater tank capacity, the sand probably receives a longer treatment. The solution tanks and zinc boxes are inside the mill.

There is a new cyanide mill at the Southern Homestake Mine, 13 miles south of Thomasville, near Cox, Randolph County.

*NOTE—The data as to the cyanide treatment was mostly obtained from Mr. W. T. Sawyer, former superintendent, checked as far as possible by Mr. Jones, the present superintendent.

The ore passes over a grizzly, the oversize from which goes through a Blake crusher, and, with the fines from the grizzly, are elevated to a trommel screen above a small storage bin. The oversize from this trommel passes through a pair of corrugated rolls, then back to the same trommel, and so on, until it is all reduced to sand. The corrugated rolls chattered badly on account of the coarse feed; and the soft clayey ore tends to stick them so it will probably be better to use instead a number of smooth rolls in series.

The fine dry ore is taken by a belt conveyor to one of the three sheet iron leaching tanks, 6 feet deep and 30 feet in diameter. It was assumed that the solution would percolate through the $5\frac{1}{2}$ feet of dry crushed ore, even though the slimes were not removed; but in the actual tests the tanks were filled only half full. Below the level of these leaching tanks are zinc boxes and sump tanks; the three solution tanks are on a trestle outside the main building, covering the leaching tanks.

The property was purchased without adequate sampling and the work was abandoned after treating 150 tons and finding that the ore averaged only \$2.00 a ton. No data as to time of treatment, strength of solution, etc., was obtained. The recovery on the three tanks tried was 70, 80 and 83 per cent respectively. The ore is decomposed rock, occurring in wide zones and carrying a great deal of clay. No data was obtained as to the capacity of the mill.

MINING DETAILS (SELF-DUMPING SKIPS, ETC.)

Many of the mines in North Carolina are based upon more or less flat veins and since most of the ore is hoisted in buckets, it is customary to sink vertical shafts. When the mines become deep, this requires expensive cross-cuts to reach the vein; hence there are many vertical shafts which are turned upon reaching the vein and not adapted to the use of a cage or an ordinary style skip. Mr. Geo. E. Price has overcome this difficulty at the Rudisill Mine, at Charlotte, Mecklenburg County, by modifying the ordinary skip, and

adapting it to his special needs. The shaft is vertical for 200 feet and then inclines at an angle of 35° from the horizontal for 150 feet more. The skip is the ordinary iron skip, except that the wheels are a little larger than usual to reduce friction on the incline and all have narrow treads. In the vertical part these wheels run between two vertical guide timbers. The rope is not over the center of the shaft but toward the dumping side so that when the skip reaches the top the front wheels run down the forward curve of the track until they strike the top. Then the rear wheels swing to the rear in the arc of a circle. Just before they reach the top of this arc the nose of the skip strikes a roller which raises the front wheels sufficiently to bring them to a bearing against the front vertical guide so that in case of overwinding the skip rises at the dumping angle and rock cannot be dumped down the shaft. In this way the skip need wait at the top of the shaft only long enough for the ore to slide out of it, which is but a small fraction of a minute.

The ore is dumped from the car on to a platform about 3 feet below the level of the rails and the skip is stopped with its top about level with this platform and nearly filling the opening in it. If the output of the mine was a little greater, Mr. Price would replace the platform by a small bin, into which the cars could be dumped as they reach the station and from which the ore could be rapidly run into a skip through a chute. But since the man that would be required to operate the gate has ample time to shovel all the ore into the skip, there would be no labor saving in the bins and no justification for the expense. For even a small mine this skip saves the labor of a top man.

In the ordinary vertical shaft the bales of the skips are fitted with shoes and there are no wheels on the skip which is unlatched and dumped at the top by rollers striking suitable curved guides. Such a skip has the advantage of needing only one set of guides and no wheels, but it cannot be operated around a curve.

The labor of the top man is also avoided by a self-dumping bucket observed at the Haile Gold Mine, South Carolina. This is an ordinary bucket fitted with guide wheels. The back wheels are caught by a latch at the dumping place and turns over when the rope is slacked off. Then the bucket is raised, the latch is withdrawn by the engineer and the bucket lowered.

CHAPEL HILL FERNS AND THEIR ALLIES

The accompanying list of ferns of this region, including an area of about two miles radius around Chapel Hill, has been in course of preparation for several years, and is now, in all probability, very nearly complete. The topography of Chapel Hill is quite favorable to fern growth, and the number found here is as large as could be expected in regions free from limestone.

In his "Catalogue of the Indigenous and Naturalized Plants of the State," by Dr. M. A. Curtis*, there are given thirty-eight true ferns and eleven fern allies for the State of North Carolina. Of the species mentioned by him, eighteen ferns and four fern allies occur in Chapel Hill, while two of the ferns in the following list are not recorded by Curtis for this State. These are *Botrychium obliquum* var. *dissectum*, and *Dryopteris Goldieana* var. *celsa*.

The list of our ferns is as follows:

BOTRYCHIUM OBLIQUUM MUHL. (*B. ternatum* Chapm.). Ternate Grape fern. Not uncommon in damp, shaded places.

BOTRYCHIUM OBLIQUUM VAR. *DISSECTUM*. Dissected Grape-fern. Found only once in a low place near Judge's spring.

BOTRYCHIUM VIRGINIANUM (L.) Sw. Virginia Grape-fern. Rather more common than *B. obliquum* and occurring in similar situations.

OSMUNDA SPECTABILIS WILLD. Royal Fern. (Distinct from *O. regalis* L. of Europe). Common along small streams.

OSMUNDA CINNAMOMEA L. Cinnamon Fern. Common along small streams and in low, damp places.

POLYPODIUM VULGARE L. Common Polypody. Very rare. Known only to occur at Upper Laurel Hill where it covers the face of a high rock, looking north.

*Geological and Natural History Survey of North Carolina, Part III, Raleigh, 1867.

POLYPODIUM POLYPODIOIDES (L.) A. S. Hitchcock. (*P. incanum* Sw.). Resurrection Fern. On shaded trunks of elms and occasionally on rocks; not rare.

PTERIDIUM AQUILINUM (L.) Kuhn. (*Pteris aquilina* L.) Bracken or Brake. In dry woods and sometimes in fields. Common.

ADIANTUM PEDATUM L. Maiden-hair Fern. Found in three situations; in rich places near the foot of hills looking north.

CHEILANTHES LANOSA (Michx.) Watt. (*C. vestita* Sw.) Hairy Lip-fern. Found only on one rock on northern side of Morgan's Creek near Scott's Hole.

ASPLENIUM PLATYNEURON (L.) Oaks. (*A. ebeneum* Ait.) Ebony Spleenwort. Common in woods and in niches of stone walls.

ASPLENIUM ACROSTICHOIDES Sw. Silvery Spleenwort. Found only in two clumps near the base of Lone Pine Hill looking north.

ASPLENIUM FELIX-FOEMINA (L.) Bernh. Lady Fern. Very common along streams and in damp places.

WOODWARDIA ARBOLATA (L.) Moore. Chain Fern. Found only in a marshy spot about one-half mile south-west of the University.

ONOCLEA SENSIBILIS L. Sensitive Fern. Scattered here and there in wet places.

DRYOPTERIS ACROSTICHOIDES (Michx.) Kuntze. Christmas Fern. Abundant along streams and on northern slopes of hills.

DRYOPTERIS THELYTERIS (L.) A. Gray. Marsh Shield-fern. Found only in marsh north of Lone Pine Hill.

DRYOPTERIS GOLDIEANA (Hook.) A. Gray. var. *celsa*. This fern was recently found near the northern foot of Lone Pine Hill. About eight specimens occurred scattered over a radius of seventy-five yards. It has not before been recorded for this State. It was described from Dismal Swamp by Palmer in the Proceedings of the Biological Society of Washington, Volume XIII, page 65, 1899. Specimens have since

been found in New York and New Jersey. For this information I am indebted to Professor L. M. Underwood and Mr. R. C. Benedict of New York. Dr. Underwood considers the fern a hybrid between *D. goldieana* and *D. marginalis*. It is not described in any of our manuals.

PHEGopteris hexagonoptera (Michx.) Fée. Beech Fern. Not uncommon in flat places along small streams.

Woodsia obtusa (Spreng) Torr. Found only on a few stone walls in town.

The fern allies found here are as follows:

Equisetum hyemale L. Scouring-rush. Found by Dr. H. V. Wilson along Morgan's Creek. Occurring also along the Oxford road near Durham.

Lycopodium alopecuroides L. Club-moss. Growing only in an open wet place near the spot where *Woodwardia* was found.

Lycopodium complanatum L. Christmas-green. Found by me only near upper Laurel Hill. Reported from a few places by others.

Selaginella apus L. Spring. Rather common among moss in wet places.

Woodsia

SALISBURY'S PHYSIOGRAPHY.*

COLLIER COBB.

Teachers of physiography in colleges will welcome this book, not only because it is the first of its kind of college grade, but also for the large amount of fresh material that it contains and its admirable arrangement, the author being at the same time a skilled investigator and a successful teacher.

"In the preparation of the text," he tells us, "the effort has been to shape it, when practicable, so as to lead the student into the subject under discussion, rather than to tell him the conclusions which have been reached by those who have made the subject their special study." The author holds persistently to that idea of physiography which regards the origin of land forms as its chief problem. This is not the English idea of physiography, but it is preëminently the American idea. It is the geography which Mackinder of Oxford defined as the study of the present in the light of the past, as distinguished from geology, which is the study of the past in the light of the present.

If the high school teacher is disappointed that small space has been given to certain topics that he has associated with text-books of physical geography, such as minerals and rocks, and plants and animals, let him remember that in colleges, where the author purposes the book shall be used, special courses in these related subjects are given in associated departments. In fact a strong point of the book is that,

*PHYSIOGRAPHY. By Prof. R. D. Salisbury, University of Chicago. 8 vo. 770 pp. American Science Series—Advanced Course. \$3.50. New York: Henry Holt and Company.

with the exception of a few references to physiographic effects on human life, scattered through its pages, it presents physiography as a science associating causes and effects clearly and forcibly, thus avoiding the mistake made by many who exalt physiographic control at the expense of a science deeply interesting for its own sake.

Any study of the origin of land forms involves the study of both air and water, since air is the medium through which solar energy is applied to the earth, and water is the greatest agent in producing effects on the earth's surface. Though the greater part of the book is given to land forms, still 273 pages remain for the treatment of the atmosphere, the ocean, and the earth's solar relations. The treatment is essentially dynamic, and the movement in the direction of the explanation of the origin of the land forms of the earth. The reader is led to see these forms in the process of becoming what they are, and to anticipate the time when they shall give way to other forms. The surface of the earth becomes a stage where physical forces play their part, now in one role, now in another, until the land above the sea is reduced to base level, or rejuvenated by elevation to begin a similar sequence of events, to enter upon a new cycle.

The first chapter of the book introduces the reader to the chief relief forms of the earth's crust and the materials out of which they are made. This general survey places the problem of the land forms well before the student, and prepares him for the consideration of the agents that have shaped them. Then follow chapters explaining and discussing the work of the atmosphere, of ground water, running water, snow and ice, of waves and currents in the construction of shore forms, of vulcanism, and the effects of crustal movement, or diastrophism. For the first time does the work of the atmosphere receive anything like adequate treatment in a text-book of physiography. These chapters are followed by a very excellent generalization and summary of the origin and distribution of land forms clinching in the minds of the students the facts that have been brought out and driven home by varied investigations.

The part played by the atmosphere in the evolution of surface forms has received a treatment comparable in detail to that presented by special text-books of meteorology. The energy derived from the sun is followed through a series of transformations, in the chapters on atmospheric pressure, the movement of air currents, and the transportation of water vapor to its final precipitation upon the earth. The various elements of climate and the zones of climate receive due attention. In these chapters the composition of the atmosphere, the air in its life relations, the distribution of temperatures over the earth, and the philosophy of the movements of the air are treated in an interesting and original manner. The chapter on the storms of the United States is especially detailed and illustrated by a complete series of isothermal charts and weather maps. Following the chapters on the atmosphere, six chapters covering fifty pages are given to the discussion of the principal facts of oceanography.

The book contains more than seven hundred illustrations, forty-three of which are sections of topographic maps; and of the others more than half are half-tones from excellent photographs. This can by no means replace field-work but serves rather to invite to work out of doors; for the author says in his preface: "Another phase of work which should not be neglected is work out of doors. This must form a part of the work of every strong course in this subject. Directions for local field-work cannot be outlined profitably in a text-book, for the work must be shaped with reference to the specific locality where the subject is studied. Both field-work and map work should have for their aim the application of the principles studied, in such a way as to make the subject vital. The aim of every laboratory exercise carried out in connection with this subject should be the same, and any laboratory work which does not either illustrate and enforce principles, or lead to them, is not worth development. The student who cannot apply what he has learned in the class-room to to his out-of-door surroundings, has not secured the maximum good from his study of the subject."

At the end of each chapter is a well selected list of topographic maps, with suggestions as to their use in relation to the text, and a list of classified and paged references for supplementary reading. These references, even without the text, would be a most valuable aid to the advanced student or teacher, as they have been gathered through long experience in the class room. The author's style is pleasing and not too technical, and the average public school teacher will find the book an invaluable aid in the teaching of physical geography, though it was written primarily for the college student.

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NO. 4

ARTIFICIAL KEY TO THE SPECIES OF SNAKES
AND LIZARDS WHICH ARE FOUND IN
NORTH CAROLINA.

1. Eyelids moveable; external ear present; underparts covered with numerous scales; limbs present, except in *Ophisaurus*. *Lizards*. 2.
Eyelids immovable; no external ears; underparts covered with broad band like plates; limbs absent. *Snakes*. 7.
2. Limbs absent. Length when adult about 2 ft. of which about two thirds are normally tail. **Glass or Joint Snake*. (*Ophisaurus ventralis*).
Limbs present. Length when adult 1 ft. or less. 3.
3. Body very smooth and shiny. 4.
Body not very smooth and shiny, scales at least somewhat rough. 5.
4. Length about 5 inches or less, unstriped. *Ground Lizard* (*Leiolepis laterale*).
Length over 5 inches or else with lengthwise stripes.
Large adults often unstriped with reddish head. *Blue-*

*The tail as in all lizards is very easy to break off, and hence a glass snake with an injured tail growing afresh, may have the tail quite short.

tailed Lizard, "Red-headed Scorpion" (*Eumeces quinque-lineatus*).

5. Back crossbanded, or else throat and sides of belly dark blue. Scales very rough. *Fence Lizard* (*Sceloporus undulatus*).

Back not crossbanded, throat not dark blue, scales not very rough. 6.

6. Back with lengthwise stripes *Sand Swift* (*Cnemidophorus sexlineatus*).

Back unstriped. Color green, brown or blackish. *Green Lizard*, "Chameleon" (*Anolis carolinensis*).

7. A pit of hollow in the side of head between eye and nostril. Plates on underside of tail mostly not in pairs. Head much broader than the neck. *The Rattlesnakes and their kin.* (*Family Crotalidae*). 8.

No pit on side of head between eye and nostril. Plates on under side of tail in pairs. Top of head covered with large plates. 11.

8. Tail with a rattle. Top of head covered with large plates. Size small. Rattle small. *Ground Rattlesnake* (*Sistrurus miliarius*).

Tail with a rattle. Top of head covered with small scales. Size large, rattle large. 9.

Tail without a rattle. Top of head covered with large plates. 10.

9. Markings on back in form of diamond-shaped blotches. *Diamond Rattlesnake* (*Crotalus adamanteus*).

Markings on back in form of dark, ragged-edged cross bands, or sometimes when the animal is very dark, wholly absent. *Banded Rattlesnake* (*Crotalus horridus*).

10. Top of head blackish brown, colors darker. **Cottonmouth* (*Ancistrodon piscivorus*).

*The Cottonmouth is continually confused with the large water snakes of the genus *Natrix*, which are perfectly harmless.

Top of head reddish, colors paler. *Copperhead* (*Ancistron contortrix*).

11. Upper parts unmarked. 12.
Upperparts with evident markings. 22.
12. Upper parts green. 13.
Upper parts not green. 14.
13. †Scales keeled. *Southern Green Snake* (*Cyclophis aestivus*).
Scales smooth. *Northern Green Snake* (*Liopeltis vernalis*).
14. Color of upper parts black. 15.
Color of upper parts some shade of brown. 17.
15. Snout recurved and keeled. Scales keeled. *Black Adder* (*Heterodon platyrhinus* var. *niger*).
Snout as usual, not recurved nor keeled. 16.
16. Scales all smooth. Underparts slaty black except the throat which is white. *Black Snake* (*Bascanion constrictor*).
Middle rows of scales faintly keeled. Underparts blackish, except for about the front third, which is white. *Chicken Snake* (*Coluber obsoletus*).
17. Scales keeled. 18.
Scales smooth. 19.
18. Size small, under 1 ft. when adult. *Brown Snake* (*Haldea striatula*).
Size large. Coppery red below. *Copperbelly* (*Natrix f. erythrogastra*).
19. Size large. (Young crossbanded, a foot long when hatched.) *Coachwhip* (*Bascanion flagellum*).
Size small, under one foot when adult. 20.

† The scales of a snake are either perfectly smooth or else with a little ridge down the middle, in the latter case they are said to be keeled.

20. Under parts reddish. *Ground Snake* (*Carphophiops amoenus*).
Under parts whitish or yellowish. 21.
21. Top of head darker than back. Color of back reddish brown. *Brown-headed Snake* (*Rhadinaea flavilata*).
Top of head same color as back. Color of upper parts grayish brown. **Valerias Snake* (*Virginia valeriae*).
22. Markings confined to red and black blotches on the sides.
Under parts red. Size large, scales smooth. *Horn Snake* (*Farancia abacura*).
Markings on upper parts confined to a light or dark cross band on neck. 23.
Back striped or spotted or both. 24.
23. Under parts white, crossband on neck black. *Crowned Tantilla* (*Tantilla coronata*).
Under parts reddish, crossband on neck white. *Brown Snake* (*Haldea striatula*), some young specimens.
Under parts yellow, spotted with black, crossband on neck, yellow. *Ringnecked Snake* (*Diadophis punctatus*).
24. Body striped lengthwise. 25.
Body not striped lengthwise. 31.
25. Scales keeled. 26.
Scales, or at least most of the lower rows, smooth. 30.
26. Under parts with dark stripes. *Willow Snake* (*Natrix leberis*).
Under parts not striped. 27.
27. Size small, under 1 ft. when adult. No side stripes but only one down the middle of back. 28.
Size larger, adults over two feet in length. Side stripes usually present. 29.
28. Under parts red. Three pale spots on nape. *Redbel-
lied Snake* (*Storeria occipitomaculata*).

**Valerias Snake* usually has small blackish dots on back, but these are not very conspicuous.

Under parts whitish. Not three pale spots on nape.
DeKays Snake (*Storeria dekayi*).

29. Side stripes on third and fourth rows of scales, counting from belly plates; no square black spots between stripes of side and that on back. *Slim Garter Snake* (*Eutaenia sirtalis*).

Side stripes on second and third rows of scales. Square black spots between stripes. *Garter Snake* (*Eutaenia sirtalis*).

30. Three red stripes on a darker ground. Underparts red, spotted with black. *Hoop Snake* (*Abastor erythrogrammus*).

Four dark stripes on a lighter ground. Underparts yellowish. *Striped Chicken Snake* (*Coluber quadrivittatus*).

31. Body above with crossbands of red, black, and white (or yellow). 32.

Body not colored as above. 34.

32. Every alternate crossbar yellow. *Coral Adder* (*Elaps fulvius*).

Every alternate crossbar black. 33.

33. Snout narrow, under parts white. *Red Snake* (*Cemophora coccinea*).

Snout rounded, under parts with black markings. *Red King Snake* (*Ophibolus doliatus coccineus*).

34. Scales all smooth. 33.

Scales keeled. 42.

35. Black with narrow white crossbars forking on the sides. *King Snake* (*Ophibolus getulus*).

Not as above. 36.

36. Underparts with squarish black spots. 37.

Underparts not with squarish black spots. 38.

37. Head large, broader than the neck. †Anal plate divided. *Spotted Racer. Rat Snake (Coluber guttatus)*.
Head small, not broader than neck. Anal plate undivided. *Milk Snake (Ophibolus doliatius triangulus)*.
38. Head large, broader than neck. Anal plate divided. 39.
Head small, not broader than neck. Anal undivided. *Brown King Snake (Ophibolus rhombomaculatus)*.
39. ‡Scales in 25 or 27 rows. 40.
Scales in 19 rows. 41.
40. Underparts yellowish. *Striped Chicken Snake, young*.
Underparts slaty black behind, whitish in front. *Chicken Snake, young*.
41. §Upper lip plates 7 on each side. *Black Snake, young*.
Upper lip plates 8 on each side. *Coachwhip, young*.
42. Snout recurved and keeled. 43.
Snout not recurved and keeled. 44.
43. Small plate just behind snout plate with several small scales round it. Snout more strongly recurved and keeled. *Hognosed Snake (Heterodon simus)*.
Small plate just behind snout plate without any small scales round it. Snout less strongly keeled and recurved. *Spreading Adder (H. platyrhinus)*.
44. Anal plate undivided. Ground color whitish with dark spots on back. *Bull Snake (Pityophis melanoleucugs)*.
Anal plate divided. 45.

†Anal plate is the plate immediately in front of the vent, which in most of our forms is divided longitudinally into two pieces, but in some it is undivided.

‡Rows of scales are counted diagonally beginning with the row just above the belly plates and are usually uneven in number.

§The upper labials or lip plates are the plates along the edge of the upper lips, excluding the plate at tip of snout.

45. Only the middle rows of scales keeled, size small.
**Chicken Snake, young.*
All rows of scales strongly keeled. 46.
46. Spots on back forming crossbars with no alternating spots on sides. *Southern Water Snake (Natrix fasciata fasciata).*
Spots on back forming crossbars on front part of body, and on hinder part alternating with spots on the sides.
Common Water Snake (Natrix fasciata Sipedon).
Spots on back alternating with spots on sides from head to tail. *Pied Water Snake (Natrix taxispilota).*

NOTES ON THE SPECIES INCLUDED IN THE KEY.

The following species are poisonous: The three species of Rattlesnake (Ground, Banded, and Diamond Rattlesnakes), the Copperhead, and the Cottonmouth, and lastly the Coral Adder, which last belongs to the same group of snakes as the deadly cobra of India. The following harmless snakes are often confused with poisonous species: the Spreading Adder with the Copperhead; the harmless water snakes with the cottonmouth, both forms being indiscriminately known as water moccasins; and the red snake and red king snake with the coral adder.

A few of the species listed have not yet been recorded from North Carolina, these are the coral adder, northern green snake, coachwhip, and milk snake, and we have only one unsatisfactory record of the bull snake.

Of the species included in the key, the following have not yet been taken in this state outside of the lower austral life zone, whose northern boundary in this state appears to be approximately a line drawn from Norfolk through Raleigh, and thence to Charlotte:

*The Southern Chicken Snake (*Coluber obsoletus confinis*) may possibly occur, in which case the keys for the young of the Chicken Snake would apply to this also. I do not know how the young of the two forms would be distinguished.

Glass Snake, at Raleigh, Garner, Southport, Beaufort.

Green Lizard, at Southport, Wilmington, Beaufort, Lake Ellis, Tryon, and Lumberton.

Hoop Snake, at Newberne, Kinston, Wilmington, Lake Ellis.

Horn Snake, at Newberne, Wilmington, Lake Ellis.

Brown headed Snake at Fort Macon.

Hognosed Snake in Wake Co., at Goldsboro and Lake Ellis.

Spotted Racer at Raleigh, Lake Ellis and Washington.

Striped Chicken Snake, at Newberne and Cape Hatteras.

Red King Snake, at Raleigh.

Red Snake at Raleigh.

Pied Water Snake at Kinston, Avoca, Newberne and Lake Ellis.

Southern Water Snake at Newberne, Wilmington, and Lake Ellis.

Crowned Tantilla at Raleigh.

Cottonmouth at Newberne, Wilmington, Lake Ellis, Cape Hatteras, Beaufort, Washington, and Raleigh.

Ground Rattlesnake, at Wilmington, and Beaufort.

Diamond Rattlesnake at Havelock below Newberne.

Records of the Coral Adder, Coachwhip, Milk Snake, Northern Green Snake, and Bull Snake are very much desired as also records of any other species of snakes and lizards, particularly those confined to the lower austral zone.

Of the four species listed as possibly occurring in the state, the Coral Adder and Coachwhip are confined to the lower austral zone, and should be looked for in the southeastern portion of the state, while the Milk Snake is most apt to be found in the northwest corner. The Northern Green Snake is apt to occur anywhere in the state but is not likely to be common anywhere, and the Bull Snake, of which we have a doubtful record from Wake Co. is liable to occur in the pine woods of the region near the coast.

The other species of snakes and lizards probably occur throughout the entire state, except in portions of the moun-

tain region, but our actual records are few and scattered.

Persons having specimens of any reptile that they are not well acquainted with, would do well to communicate with the Curator of the State Museum at Raleigh, or with myself.

C. S. BRIMLEY,
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(Information is also desired concerning the occurrence of the alligator in the state and also as to the occurrence of the species of soft shelled turtles in the Mississippi drainage as well as in the southeast of the state, the two different parts in which they may possibly occur.)

THE SALAMANDERS OF NORTH CAROLINA

C. S. BRIMLEY

Salamanders are animals which are commonly confused with lizards and which mainly resemble them in external appearance. Their true affinities, in spite of the possession of limbs, are however with the fishes, with which group they and the other amphibians are sometimes combined under the name of Ichthyopsida.

They differ externally from all our lizards in the possession of a moist skin without scales, while all our lizards have a dry scaly skin. The skin in salamanders and other amphibians (frogs and toads) is always moist, and used to some extent (wholly in many species) as an organ of respiration.

The forms which occur or are liable to occur in this state may be recognized by the following key.

KEY TO THE SALAMANDERS OCCURRING OR LIABLE TO OCCUR IN NORTH CAROLINA

1. Adults with external gills, 2.
Adults without external gills, 5.
2. Hind limbs absent, 3.
Hind limbs present. Toes 4 on both hind and forefeet, 4.
3. Toes 4. Size large. *Great Siren* (*Siren lacertina*).
Toes 3. Size small. *Little Siren* (*Pseudobranchius striatus*).
4. Brown with darker spots. Water Dog (*Necturus maculatus*).

Pale unspotted. *Southern Water Dog* (*Necturus punctatus*).

5. Adults with a rounded opening on each side of neck, 6.
Adults without a rounded opening on each side of neck, 7.
6. Body eel-shaped, with rudimentary limbs. Toes 2 or 3 each on both fore and hind feet. *Ditch Eel* (*Amphiuma means*).
Body stout, salamander shaped. Toes 4 on fore, 5 on hind feet. *Hellbender* (*Cryptobranchus alleghaniensis*).
7. Tongue mushroom shaped, i. e. a circular disk on a central stalk, 8.
Tongue not attached by a central stalk only, 15.
8. Toes on hind feet 4. Size very small, yellowish brown. *Dwarf Salamander* (*Manculus quadridigitatus*).
Toes on hind feet 5. (Genus *Spelerpes*), 9.
9. *Costal grooves, 13 or 14. 10.
Costal grooves 15 to 17. 13.
10. Tail about as long as rest of body. Yellow with a dark line along each side of back. Underparts unmarked. *Striped Salamander* (*S. bilineatus*).
Tail 1 1-2 to 2 times as long as body. 11.
11. Color vermilion red, with many brown spots. Tail spotted, not barred. *Spotted tailed Triton* (*S. maculicaudus*).
Color yellow. 12.
12. Underparts marbled with black. Back with a black stripe down middle and another on each side. *Holbrook's Triton* (*S. guttolineatus*).
Underparts unmarked. Back and sides with irregular black spots. *Long-tailed Salamander* (*S. longicauda*).

*Costal grooves are grooves on the sides indicating where the ribs are.

13. *Upper jaw bearing on its margin, immediately below each nostril, a prominent tubercle. Color light chocolate brown, spotted with brown. Underparts unmarked. *Daniel's Salamander* (*S. danieli*).
Upper jaw bearing no such tubercle. 14.
14. Color red of varying shades spotted above or below with black or both. *Red Triton* (*S. ruber*).
Color yellowish or purplish brown above, irregularly blotched with gray. *Purple Salamander* (*S. porphyriticus*).
15. Head with three longitudinal grooves. Underparts yellow or red below with black dots. 16.
Head without longitudinal grooves. 17.
16. Each side with a row of red spots, each spot surrounded by a black ring. *American Newt* (*Diemyctylus viridescens*).
Each side with a series of black bordered red lines, replacing the black ringed spots. *Wilmington Newt* (*D. v. vittatus*).
17. Salamanders with rather long toes on all four feet, the outer and inner ones well developed. Tail compressed. (Genus *Ambystoma*). 18.
Salamanders with shorter toes, the outer or inner toes or both usually reduced in size or rudimentary. Tail not much compressed. 26.
18. Costal grooves 10. Form short and stout. Color blackish brown with gray, lichen like markings. *Mole Salamander* (*A. talpoideum*).
Costal grooves more than 10. 19.
19. Costal grooves usually 11. 20.
Costal grooves 14. 23.

*Similar tubercles occur more or less frequently in *Manculus quadrigitaus*, *Sp. bilineatus*, *Sp. guttolineatus* and regularly in *Sp. maculicauda*.

20. Bluish black with gray or white blotches or crossbars on the upper parts of head, body and tail, usually about 12 or 14 in all. Underparts unmarked. *Marbled Salamander* (*A. opacum*).
Not as above. 21.
21. Black with a series of large round yellow spots down each side of back. A strong dorsal groove. *Spotted Salamander* (*A. punctatum*).
Lead colored with one or two series of small yellow spots along sides. No dorsal groove, size small. *Smaller Spotted Salamander* (*A. conspersum*).
Not as above. 22.
22. Dark brown, yellowish below. No markings. *Sope's Salamander* (*A. Sopeanum*).
Olive brown, yellowish below. Limbs banded, tail spotted. A few ill-defined yellowish spots above. *Two colored Salamander* (*A. bicolor*).
23. Markings grayish or whitish. 24.
Markings brown or yellow. 25.
24. Olive brown or blackish with pale or bluish spots, these sometimes absent. *Jefferson's Salamander* (*A. jeffersonianum*).
Black with a narrow gray line between each pair of costal folds, these either crossing the back undivided to meet their fellows from the opposite side or forking to meet a similar fork from the other side. Underparts thickly speckled with gray. *Banded Salamander* (*A. cingulatus*).
25. Tail very long, much longer than head and body. *Ohio Salamander* (*A. xiphias*).
Tail about as long as head and body. Color varying from uniform brown to yellow, but usually spotted. *Tiger Salamander* (*A. tigrinum*).
26. Toes on hind feet 4. Underparts with dots like ink spots. *Scaly Salamander* (*Hemidactylium scutatum*).
Toes on hind feet 5. 27.

27. Head with enlarged pores, which give it a pitted appearance. Underparts usually with black dots. Sides with dark longitudinal stripes. *Margined Salamander* (*Stereochilus marginatus*).
Not as above. 28.
28. Tail compressed and finned at least for the apical two thirds. 29.
Tail rounded. 32.
29. Color wholly black above and below. *Black Triton* (*Desmognathus nigra*).
Color not all black. 30.
30. Snout very flat, broad and depressed. Yellowish buff, thickly marked above with confluent black blotches. Underparts unmarked. *Moore's Triton* (*Leurognathus marmoratus*).
Snout more or less arched. 31.
31. Skin of head granulated. Underparts usually more or less uniform slate color. Size rather large. *Mountain Triton* (*Desmognathus quadrimaculatus*).
Skin of head not granulated. Underparts pale. *Brown Triton* (*Desmognathus fusca*).
32. Color brownish yellow, often spotted. *Yellow Salamander* (*Desmognathus ochrophea*).*
Color blackish or plumbeous. (Genus *Plethodon*.) 33.
33. Color lead-colored with a chestnut red dorsal band, size small. *Redbacked Salamander* (*P. erythronotus*).
Color uniform lead color. *Plumbeous Salamander* *P. e. cinereus*).
Color black with various markings. 34.
34. Black with red legs. *Sherman Salamander* (*P. Shermani*).

*All the species of the the genus *Desmognathus* have a peculiar physiognomy which is very characteristic, but not easy to describe.

Black with an orange yellow stripe on sides of head and neck. *Jordan Salamander* (*P. jordanii*).

Black with bluish white blotches and specks, occasionally unspotted. *Slimy Salamander* (*P. glutinosus*).

Black with yellowish green blotches of irregular form on back and sides. *Bronzy Salamander* (*P. aeneus*).

Of the above species the following have not yet been taken in the state: Little Siren, Spotted-tailed Triton, Long-tailed Salamander, Smaller spotted Salamander, Cope's Salamander, Two-colored Salamander, Banded Salamander, Ohio Salamander, Scaly Salamander, Jordan Salamander, Bronze Salamander. Most of these however may possibly occur, and some of them are almost certain to be secured with more careful and complete collecting.

The species known to occur in the State have been collected in the following localities:

Great Siren. Craven Co., New Hanover Co.

Water Dog. Wake.

Southern Water Dog. New Hanover.

Ditch Eel. Wake, Edgecombe, Dare, Bertie and Craven.

Hellbender. Yancey.

Dwarf Salamander. Wake, Lenoir.

Striped Salamander. Wake, Buncombe, Yancey, Mitchell and Forsyth.

Holbrook's Triton. Wake, Buncombe, Forsyth, and valley of French Broad.

Daniel's Salamander. Yancey.

Red Triton. Wake, Buncombe, Mitchell, Carteret, Yancey, Burke, Orange, Wayne, Forsyth and Henderson.

Purple Salamander. Mitchell.

American Newt. Wake, Henderson, Lenoir.

Wilmington Newt. New Hanover.

Mole Salamander. Valley of French Broad.

Marbled Salamander. Wake, Edgecombe, Guilford, Columbus, Forsyth, Lenoir.

Spotted Salamander. Wake.

- Tiger Salamander. Moore.
 Jefferson Salamander. Mitchell.
 Redbacked Salamander. Mitchell, Pitt (same localities
 for Plumbeous S).
 Margined Salamander. Craven.
 Black Triton. Mitchell.
 Moore's Salamander. Grandfather Mt.
 Mountain Salamander. Yancey, Mitchell, Henderson.
 Brown Triton. Wake, Craven, Forsyth, Lenoir.
 Yellow Triton. Yancey, Mitchell.
 Sherman Salamander. Nantahala Mt.
 Slimy Salamander. Whole State.

A KEY TO THE SPECIES OF FROGS AND TOADS
LIABLE TO OCCUR IN NORTH CAROLINA

C. S. BRIMLEY

1. Upper jaw without any teeth. 2.
Upper jaw with teeth. 5.
2. Skin smooth. Size small. Snout pointed. No paratoid glands (just behind ear). Hind feet not webbed. *Toothless Frog* (*Engystoma carolinense*).
Skin warty. Paratoids large. Hind feet little webbed. Head with bony ridges above. Toads. 3.
3. Size small, length of head and body one inch. Skin very rough. Bony ridges turning inward almost at right angles just back of the eyes. *Dwarf Toad* (*Bufo quercicus*).
Size larger, adults about 3 or 4 inches long. Skin not so rough. Bony ridges on top of head not turning abruptly inward back of eyes. 4.
4. Bony ridges ending in a knob behind. *Southern Toad* (*B. lentiginosus*).
Bony ridges not ending in a knob behind. *Common Toad* (*B. l. americanus*).
5. Paratoids present. Hind feet webbed. Heel with a flat, sharp-edged spur. *Solitary Spadefoot Scaphiopus holbrooki*.
Paratoids absent. No sharp edged spur on heel. 6.
6. Fingers and toes dilated at their tips, this dilation forming a viscous disk. Tree frogs. 7.
Fingers and toes not much dilated at tips. 13.

7. Back with a dark x-shaped mark, size small. *Peeper* (*Hyla pickeringi*).
Back marked or not, but if marked, the markings do not form an x-shaped mark. 8.
8. Back of thigh not marked with yellow spots or variegations. 9.
Back of thigh with yellow spots or variegations. 11.
9. A yellow band on upper lip and sides of body, sharply defined above and below. Back with minute yellowish spots. *Carolina Tree Frog* (*Hyla cinerea*).
Yellow or white band on sides not sharply defined above and below. 10.
10. Size large, feet edged with yellow. *Georgia Tree Frog* (*H. gratiosa*).
Size small, feet not edged with yellow. *Squirrel Tree Frog* (*H. squirella*).
11. Size large, skin of back rough. A light spot on upper jaw just below eye. *Common Tree Frog* (*H. versicolor*).
No light spot below eye. 12.
12. A plum colored line along sides of body with yellow spots below it. *Anderson's Tree Frog* (*H. andersoni*).
No yellow spots on sides. *Pine woods Tree Frog* (*H. femoralis*).
13. Feet unwebbed, size small. (Genus *Chorophilus*). 14.
Feet more or less webbed. 15.
14. Skin of upper surface granulated. *Chorus Frog* (*C. nigratus* and subspecies).
Skin of upper surface smooth, a dark patch on ear. *Smooth Chorus Frog* (*C. occidentalis*).
15. Size small. Skin above warty. A dark triangle between eyes. *Cricket Frog* (*Acris gryllus*).
Size larger. Skin above smooth. 16.
16. A ridge of raised skin along each side of back. 17.
No narrow ridge of raised skin along side of back. 19.

17. A black ear patch. *Wood Frog (Rana sylvatica)*.
No black ear patch. 18.
18. Fold of skin down each side of back white. Back with large dark spots. *Leopard Frog (Rana pipiens)*.
Fold of skin down each side of back the same color as back. Back with a few small dark spots or none.
Spring Frog (Rana clamata).
19. Back with large dark spots in two rows. Size medium.
Pickerel Frog (Rana palustris).
Back with irregular dark spots or none. Size large.
Bullfrog (Rana catesbiana).
Sides with two light brown longitudinal bands. *Cope's Frog (Rana virgatipes)*.

Of the species included in the key the following have not yet to my knowledge been recorded from North Carolina: Anderson's Tree Frog, Georgia Tree Frog, Smooth Chorus Frog, and Southern Toad.

The other species have been taken in the following localities:

Toothless Frog. Wake, Johnston and Wayne Co's.

Dwarf Toad. Lenoir and Carteret.

Common Toad. Forsyth, Wake, Jackson, Craven, Lenoir and Wayne.

Solitary Spadefoot. Wake.

Peeper. Wake, Mitchell, Wayne, Johnston, Guilford.

Carolina Tree Frog. Lenoir and Dare.

Squirrel Tree Frog. Dare, Craven, Brunswick.

Pine woods Tree Frog. Craven and New Hanover.

Common Tree Frog. Wake, Wayne, Forsyth Pitt.

Chorus Frog. Guilford and Wake.

Cricket Frog. Wake, Craven, Wayne, Forsyth, Guilford.

Wood Frog. Lenoir.

Pickerel Frog. Wake, Mitchell, Lenoir.

Leopard Frog. Wake, Craven, Edgecombe, Dare.

Spring Frog. Craven, Wake, Forsyth, Guilford, Mitchell.

Bullfrog. Wake, Craven, Edgecombe.

Cope's Frog. Craven.

These keys (to snakes and lizards, salamanders, and to toads and frogs) have been prepared with the idea of giving intelligent persons without special knowledge on the subject an opportunity of identifying our native forms of these groups. The keys must not be expected to be infallible though I have endeavored to make them as accurate as possible.

ON SOME PHENOMENA OF COALESCENCE AND REGENERATION IN SPONGES¹

BY H. V. WILSON

I

In a recent communication I described some degenerative and regenerative phenomena in sponges and pointed out that a knowledge of these powers made it possible for us to grow sponges in a new way. The gist of the matter is that silicious sponges when kept in confinement under proper conditions degenerate in such a manner that while the bulk of the sponge dies, the cells in certain regions become aggregated to form lumps of undifferentiated tissue. Such lumps or plasmodial masses, which may be exceedingly abundant, are often of a rounded shape resembling gemmules, more especially the simpler gemmules of marine sponges (*Chalina*, *e. g.*), and were shown to possess in at least one form (*Stylotella*) full regenerative power. When isolated they grow and differentiate, producing perfect sponges. I described moreover a simple method by which plasmodial masses of the same appearance could be directly produced (in *Microciona*). The sponge was kept in aquarium until the degenerative process had begun. It was then teased with needles so as to liberate cells and cell agglomerates. These were brought together with the result that they fused and formed masses similar in appearance to those produced in this species when the sponge remains quietly in aquarium. At the time I was forced to

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leave it an open question whether the masses of teased tissue were able to regenerate the sponge body.

During the past summer's work at the Beaufort Laboratory I again took up this question and am now in a position to state that the dissociated cells of silicious sponges after removal from the body will combine to form syncytial masses that have power to differentiate into new sponges. In *Microciona*, the form especially worked on, nothing is easier than to obtain by this method hundreds of young sponges with well developed canal system and flagellated chambers. How hardy sponges produced in this artificial way are and how perfectly they will differentiate the characteristic skeleton, are questions that must be left for more prolonged experimentation.

Taking up the matter where it had been left at the end of the preceding summer, I soon found that it was not necessary to allow the sponge to pass into a degenerative state, but that the fresh and normal sponge could be used from which to obtain the teased out cells. Again in order to get the cells in quantity and yet as free as possible from bits of the parent skeleton, I devised a substitute for the teasing method. The method adopted is rough but effective.

Let me briefly describe the facts for *Microciona*. This species (*M. prolifera* Verr.) in the younger state is incrusting. As it grows older it throws up lobes and this may go so far that the habitus becomes bushy. The skeletal framework consists of strong horny fibers with embedded spicules. Lobes of the sponge are cut into small pieces with scissors and then strained through fine bolting cloth such as is used for tow nets. A square piece of cloth is folded like a bag around the bits of sponge and is immersed in a saucer of filtered sea-water. While the bag is kept closed with the fingers of one hand it is squeezed between the arms of a small pair of forceps. The pressure and the elastic recoil of the

I am indebted to the director of the station, Mr. H. D. Aller, for his kindly aid in supplying all facilities needed in the course of my investigation.

skeleton break up the living tissue of the sponge into its constituent cells, and these pass out through the pores of the bolting cloth into the surrounding water. The cells, which pass out in such quantity as to present the appearance of red clouds, quickly settle down over the bottom of the saucer like a fine sediment. Enough tissue is squeezed out to cover the bottom well. The cells display amœboid activities and attach to the substratum. Moreover they begin at once to fuse with one another. After allowing time for the cells to settle and attach, the water is poured off and fresh sea-water added. The tissue is freed by currents of the pipette from the bottom and is collected in the center of the saucer. Fusion between the individual cells has by this time gone on to such an extent that the tissue now exists in the shape of minute balls or cell conglomerates of a more or less rounded shape looking to the eye much like small invertebrate eggs. Microscopic examination shows that between these little masses free cells also exist, but the masses are constantly incorporating such cells. The tissue in this shape is easily handled. It may be sucked up to fill a pipette and then strewn over cover glasses, slides, bolting cloth, watch glasses, etc. The cell conglomerates which are true syncytial masses throw out pseudopodia all over the surface and neighboring conglomerates fuse together to form larger masses, some rounded, some irregular. The details of later behavior vary, being largely dependent on the amount of tissue which is deposited in a spot, and on the strength of attachment between the mass of tissue and the substratum.

Decidedly the best results are obtained when the tissue has been strewn rather sparsely on slides and covers. The syncytial masses at first compact and more or less rounded, flatten out, becoming incrusting. They continue to fuse with one another and thus the whole cover glass may come to be occupied by a single incrustation, or there may be in the end several such. If the cover glass is examined at intervals, it will be found that differentiation is gradually taking place. The dense homogeneous syncytial mass first develops at

the surface a thin membrane with underlying connective tissue (collenchyma). Flagellated chambers make their appearance in great abundance. Canals appear as isolated spaces which come to connect with one another. Short oscular tubes with terminal oscula develop as vertical projections from the flat incrustation. If the incrustation be of any size it produces several such tubes. The currents from the oscula are easily observed, and if the cover glass be mounted in an inverted position on a slide the movements of the flagella of the collar cells may be watched with a high power (Zeiss 2 mm.). This degree of differentiation is attained in the course of six or seven days when the preparations are kept in laboratory aquaria (dishes in which the water is changed answer about as well as running aquaria). Differentiation goes on more rapidly when the preparation is hung in the open harbor in a live-box (a slide preparation inclosed in a coarse wire cage is convenient). Sponges reared in this way have been kept for a couple of weeks. The currents of water passing through them are certainly active and the sponges appear to be healthy. In such a sponge spicules are present, but some of these have unquestionably been carried over from the parent body along with the squeezed out cells.

The old question of individuality may receive a word here. *Microciona* is one of that large class of monaxonid sponges which lack definite shape and in which the number of oscula is correlated simply with the size of the mass. While we may look on such a mass from the phylogenetic standpoint as a corm, we speak of it as an individual. Yet it is an individual of which with the stroke of a knife we can make two. Or conversely it is an individual which may be made to fuse with another, the two forming one. To such a mass the ordinary idea of the individual is not applicable. It is only a mass large or small having the characteristic organs and tissues of the species but in which the shape of the whole and the number of the organs are indefinite. As with the adult so with the lumps of regenerative tissue. They have no definiteness of shape or size, and their structure is only definite

in so far as the histological character of the syncytial mass is fixed for the species. A tiny lump may metamorphose into a sponge, or may first fuse with many such lumps, the aggregate also producing but a single sponge although a larger one. In a word we are not dealing with embryonic bodies of complicated organization but with a reproductive or regenerative tissue which we may start on its upward path of differentiation in almost any desired quantity. A striking illustration of this nature of the material is afforded by the following experiment. The tissue in the shape of tiny lumps was poured out in such wise that it formed continuous sheets about one millimeter thick. Such sheets were then cut into pieces, each about one cubic millimeter. These were hung in bolting cloth bags in an outside live-box. Some of the pieces in spite of such rough handling metamorphosed into functional sponges.

Even where the embryonic bodies of sponges have a fixed structure and size, as in the case of the ciliated larva, the potential nature as displayed in later development, is not fixed in the matter of individuality. Such a body may form a single individual or may fuse with some of its fellows to form a larger individual differing from the one-larva sponge only in size. It is then in spite of its definiteness of shape and size, essentially like a lump of regenerative tissue in that whether it develops into a whole sponge or a part of a sponge depends not on its own structure but on whether it is given a good opportunity of fusing with a similar mass. A parallel case to the coalescence of larvæ is afforded by the gemmules of fresh water sponges. Mr. M. E. Henriksen in a manuscript account submitted to me a year ago, describes the fusion of gemmules to form a single sponge.

In the preceding description I have passed over the question as to the precise nature of the cells which combine to form the masses of regenerative tissue. On this point as on the histological details in general I hope to have more to say later. Nevertheless the phenomena are so simple that observation of the living tissue reveals much, probably indeed all

that is of fundamental importance. If a fairly dense drop of the squeezed out tissue be mounted at once and examined with a high power (Zeiss 2 mm., comp. oc. 6), the preparation is seen to consist of fluid (sea-water) with a few spicules and myriads of separate cells. The cells fall into three classes.

1 The most conspicuous and abundant are spheroidal, reddish, densely granular, and about 8μ in diameter. These cells which can be nothing but the unspecialized, amoeboid cells of the mesenchyme (amoebocytes or archæocytes), put out hyaline pseudopodia that are sometimes elongated, more often rounded and blunt.

2 There is also a great abundance of partially transformed collar cells, each consisting of an elongated body with slender flagellum. The cell is without the collar, the latter doubtless having been retracted. In the freshly prepared tissue the flagella are vibratile, the cells moving about. Soon however the flagellum ceases to vibrate.

3. The third class is not homogeneous. In it I include more or less spheroidal cells ranging from the size of the granular cells down to much smaller ones. Many of these are completely hyaline, while others consist of hyaline protoplasm containing one or a few granules.

Fusion of the granular cells begins immediately and in a few minutes time most of them have united to form small conglomerate masses which at the surface display both blunt and elongated pseudopodia. These masses soon begin to incorporate the neighboring collar and hyaline cells. One sees collar cells sticking fast by the end of the long flagellum to the conglomerate mass. Other collar cells are attached to the mass by short flagella. Still again only the body of the collar cell projects from the mass while there is no sign of flagellum. Similarly spheroidal hyaline cells of many sizes are found in various stages of fusion with the granular conglomerate. In such a preparation the space under the cover glass is soon occupied by innumerable masses or balls of the kind just described, between which continue to lie abundant free cells, some collar cells, others hyaline. Practically all

the granular cells go to make up the balls. The play of pseudopodia at the periphery of such balls, which results in the incorporation of free cells and in the fusion of balls to form larger masses, is easily watched. Along with such a cover glass preparation it is convenient to have some of the squeezed-out tissue in a watch glass of sea-water. In the watch glass preparation it is instructive to watch with a two-thirds or one-half objective the fusion of the cell conglomerates to form masses like those strewn on covers, slides, etc.

These observations on the early steps in the formation of the masses of regenerative tissue make it plain that such masses are composed chiefly of the spheroidal, granular cells (amoebocytes or archæocytes), but that nevertheless other cells, collar cells and more or less hyaline cells also enter into their composition. I may recall the fact that in the formation of regenerative masses in a degenerating sponge,³ the evidence from sections, which is the only evidence available in the case, points to the conclusion that the collar cells help to form the syncytial tissue of the masses. The question of interest lying at the heart of this matter may be so formulated: can particles of the *Microciona* protoplasm differentiate into functional collar cells and, when the occasion arises, change back into unspecialized masses capable of combining with other masses of unspecialized protoplasm to form a regenerative body? The facts to which I have just alluded support this idea, and indicate that the immediate problem is one worth pursuing farther as a good case of temporary differentiation of protoplasm in the metazoa analogous to the temporary specialization of the cell individual which occurs in such colonial protozoa as *Protospongia*.⁴

As far as the amoebocytes are concerned it is certain that they have great regenerative power. Weltner in a recent

³ A new method by which sponges may be artificially reared, *Science*, n. s., vol. xxv, no. 649, 1907.

⁴ Metschnikoff, *Embryologische Studien an Medusen*, p. 147, 1886.

paper⁵ has emphasized the importance of these unspecialized cells in the process of growth and regeneration. His conclusions which refer directly to fresh water sponges, are that in a growing sponge, in a sponge regenerating new organs after its winter period of simplification, and in the regeneration of a sponge from a cutting, the amoebocytes are the all-powerful elements in that they give rise to all the new tissues formed. He further alludes to the fact that such reproductive bodies as the gemmules of fresh water sponges and the buds of *Tethya* (according to Maas) are only groups of amoebocytes; further that the gemmules of *Tedania* and *Esperella* described by Wilson as developing into ciliated larvæ, and the similar bodies found by Ijima in hexactinellids, are such groups. I may add that the presence of such groups of unspecialized cells in the hexactinellids has recently been confirmed by the master in sponge-morphology, F. E. Schulze, who recognizes the probability of their reproductive nature and gives them a new name, that of *sorites*.⁶ It is clear then that in many sponges reproductive bodies are formed by the association of unspecialized amoeboid cells. But there is nothing in this fact which precludes the possibility that the groups of amoebocytes are in part recruited from transformed collar cells and other tissue cells, such as pinacocytes (flat cells of canal walls), that have undergone regressive differentiation into an unspecialized amoeboid condition.

Cells analogous to the amoebocytes of sponges are found elsewhere in the metazoa, *e. g.*, in the ascidians.⁷ It would be interesting to know what capacity, if any, for development they have, when freed from the parent (bud) and collected together in sea-water.

⁵ Spongilliden-studien V. Zur Biologie von *Ephydatia fluviatilis* und die Bedeutung der Amœbocyten für die Spongilliden. Archiv für Naturgeschichte, 73 Jahrg., 1 Bd., 2 Heft, 1907.

⁶ Wissensch. Ergebn. d. Deutsch. Tiefsee-Exp. 1898-99. Hexactinellida, pp. 213-15. Jena, 1904.

⁷ Comp. Hjort's and Lefevre's papers on budding in ascidians.

II

I shall here briefly record some experiments which gave only negative results but which under circumstances admitting of a wider choice of species, ought to yield returns of value. These experiments were based on the assumption that if the dissociated cells of a species will recombine to form a regenerative mass and eventually a new sponge, the dissociated cells of two different species may be made to combine and thus form a composite mass bearing potentially the two sets of species-characteristics. It is clear that such an organism would be analogous to one produced by an association of the blastomeres of the two species. Pending the successful carrying out of this experiment, it would be idle to discuss further the nature of the hypothetical dual organism.

In my own experiments three sponges were used: *Microciona*, *Lissodendoryx* and *Stylotella*. The three are all monactinellids but *Microciona* is the only one in which the skeleton includes any considerable amount of horny substance. Dissociated cells of *Microciona* and *Lissodendoryx* were mixed, and again dissociated cells of *Microciona* were mixed with those of *Stylotella*. In each case the experiment was performed at two different times, and a considerable number of admixtures, in watch glasses and on cover glasses, was made. The preparations were examined at short intervals with the microscope. The cells of these three species are colored very differently, and are therefore easily distinguished, at least as soon as fusion sets in and little masses of cells begin to be formed. In all the experiments the cells and cell-masses of a species combined and not the cells of different species. Thus in the admixture of *Microciona* and *Lissodendoryx*, *Microciona* regenerative masses and *Lissodendoryx* regenerative masses were produced. Similarly when *Microciona* and *Stylotella* cells were mixed, the resultant masses were pure, some *Microciona*, some *Stylotella*. The *Microciona* masses in these experiments were hardy. They continued to develop and in some preparations metamorphosed. The cell masses of the other two species while they reached a considerable size were

not hardy, most dying soon although some began the process of metamorphosis.

These three species are so unlike that there was little ground in the beginning for the expectation that coalescence would take place. Possibly as in the cases where fusion of egg and sperm of different species is induced through some alteration in the physiological state of protoplasm, so the generative cells and cell masses of different species may be made to combine under abnormal conditions. The more promising task is however to find allied species and subspecies, the regenerative tissue of which will combine under natural conditions. Such forms, I take it, should be sought among the horny sponges and the monactinellids with abundant horny matter.

III

The tendency to fuse so vigorously displayed by the cells and cell masses of regenerative tissue led me to examine into the power that larvæ have to fuse with one another and the capacity for development in the resultant mass. Delage and others have remarked on the not infrequent occurrence of fusion between sponge larvæ. Delage⁸ says that he has often observed two or several larvæ unite to form a single sponge "which has from the start several cloacas."

I find that this power to fuse displayed by the larvæ is one that is easy to control. Fusion between the larvæ will readily take place if they are brought in contact at the critical time when the ciliated epithelium is being replaced by the permanent flat epithelium. At this time they will fuse in twos or threes or in larger number up to and over one hundred. The smaller composite masses composed of as many as five or six larvæ metamorphose into sponges. The larger masses composed of many larvæ did not metamorphose in my experiments but experience with the regenerative tissue suggests that such masses would metamorphose if certain mechanical difficulties due to the great size of the mass were

⁸ Embryogénie des Eponges. Arch. de Zool. Exp. et Gén., p. 400, 1892.

removed. Possibly this might be accomplished by cutting a flattened sheet composed of some hundred larvæ (such as I have produced) into pieces and inducing the pieces to metamorphose separately.

I may now describe some of the details in this process of larva-fusion. In a species of *Lissodendoryx* used the larva is of the following character. It has the usual ovoidal shape with a protuberant non-ciliated pole. The anterior pole is somewhat truncated and is sparsely ciliated. The rest of the body bears the usual thick covering of cilia. As seen with reflected light the bulk of the body is dead white, the posterior pole deep blue, and the anterior pole bluish. This coloration is not absolutely fixed for the species, but the larvæ used in my coalescence experiments were all of this character. Within twenty-four hours after liberation the ciliated larvæ are creeping (remaining in contact with the bottom as they swim) over the bottom of the dish. Some are now put in deep round watch glasses and with pipette and needle coaxed together into a clump. Fusion soon begins and on the next day plenty of composite larvæ are present. The larvæ fuse endwise, for the most part in pairs. The compound larva so produced owing to its weight has a very feeble locomotory power. Using pairs that are nearly motionless, larvæ may be brought together (coaxed with needle) and arranged in a desired position on a cover glass for instance. In successful cases fusion results before the separate masses move apart. In this way, selecting an instance, I have added to one arm of a quadruple mass a pair of larvæ, and to the opposite arm two pairs,

For the purpose of bringing about the fusion of many larvæ the following simple method is convenient. Suppose that we have the larvæ in a paraffine-coated dish, and they are in a late "creeping" stage. Small excavations, 2-3 mm. deep and 4-5 mm. wide, are now made in the paraffine, and with the pipette the larvæ are driven into the holes. They lie here in numbers up to and over one hundred, crowded together and heaped upon one another. Fusion begins soon

and the larvæ are gradually converted into a flattened cake. The larger cakes thus made measured four by three millimeters. The body of such a cake is a continuous flattened mass in which there is no indication of the component larvæ, but the rounded ends of the larvæ that have last fused with the general mass remain for a time distinguishable. Owing to their blue coloration the ends of the larvæ may be recognized in these and the other compound masses even after the outline of the larva has been completely lost.

As already stated the smaller compound masses metamorphose without difficulty. The coalesced larvæ may be made to attach to cover glasses, slides, etc. Larger masses composed of about twenty larvæ underwent a partial metamorphosis. Such masses were laid upon bolting cloth to which they readily attached. The larger masses were hung in small bolting cloth bags in a live box. Whether owing to bad handling or more probably to some inherent difficulty, they did not metamorphose but soon died.

The ease with which larvæ of the same species may be made to fuse together suggests that larvæ of different species might likewise be induced to coalesce. Some experiments along this line could not fail to be of interest.

IV

In the tendency to fuse with the production of a plasmodium, the dissociated cells of sponges resemble the amoebocytes (amoebulæ) of the mycetozoa and *Protomyxa*. The regenerative power of the plasmodium has an interest both theoretical and economic in itself. But it is the tendency to fuse displayed by the cells that have been forcibly broken apart, which constitutes the fact of most general physiological importance. Discarding for the moment the word "cell" and speaking of the protoplasm of a species as a specific substance, the phenomena may be restated to advantage in the following way.

A mass of sponge protoplasm in the unspecialized state typically exhibits pseudopodial activities at the surface. In

lieu of more precise knowledge it is useful to regard the pseudopodia as structures which explore and learn about the environment. On coming in contact two masses of the same specific protoplasm tend to fuse. This tendency is probably useful (*i. e.*, adaptive) in that the additional safety (from enemies and "accidents") accruing from increase in size of the mass more than compensates for the reduction in number of the individual masses that start to grow (rearing of sponges shows that masses of good size frequently withstand conditions that effectually wipe out the very small masses.) Unlike specific substances (protoplasms of quite different species) do not tend to fuse.

To the many biologists who have found ideas and observations of deep interest in the papers on protoplasmic activities by Professor and Mrs. E. A. Andrews (G. F. Andrews), the statement just made will have a familiar sound. Mrs. Andrews in her essay on *The Living Substance as Such and as Organism*⁹ and her paper on *The Spinning Activities of Protoplasm*¹⁰ makes, it would appear from subsequent confirmations, a definite advance in our knowledge of the intimate structure of protoplasm. But it is her generalizations, based on singularly acute observations, with respect to the *behavior* of protoplasm, that have especially influenced my own work. The particular generalizations referred to may be so formulated:

1 Protoplasm tends to produce a viscous, pellicular layer with formation of pseudopodial outgrowths over the surface, whether external or internal to the mass, which establishes contact with the environmental medium.

2 Pseudopodia from adjacent masses of the same specific substance tend to fuse. Thus actual connections which can be made and remade, and along which transference of substance takes place, are established between the masses.

That these phenomena are observable in widely separated groups of metazoa has been also shown by Professor Andrews

⁹Suppl. to Journ. Morphology, vol. xii, no. 2, 1897.

¹⁰Journ. Morphology, 1897.

in a series of brief studies marked with his well known skill and accuracy of observation and statement. I fully agree with him as to the great importance of the facts.

The general point of view entertained by Mrs. Andrews in her much discussed essay is perhaps not everywhere clear to me. It is manifest however that she consistently subordinates the idea of the individual, whether entire organism or cell, to that of the specific substance of which it is but a more or less detached piece. As far as the cell is concerned this point of view seems to be essentially that of Sachs and Whittman. Mrs. Andrews extends it to the whole organism, and I may say that this way of looking at an animal or plant (or piece of the same) is in my opinion a habit of mind that will justify itself and indeed is doing so today, in that it leads to discoveries concerning the nature of protoplasms as revealed by what they can do.

University of North Carolina,
Chapel Hill, N. C.
October 29, 1907.

FISHES OF NORTH CAROLINA; A REVIEW

BY JOSEPH HYDE PRATT

There has just been issued by the North Carolina Geological and Economic Survey Volume II on The Fishes of North Carolina. This volume has been prepared for the Survey by Dr. H. M. Smith, Deputy U. S. Commissioner of Fisheries. The object of this publication is to give to the people of North Carolina and to others a more accurate knowledge of the abundance, distribution, habits, migrations, spawning, food value, etc., of the fishes in the belief that such knowledge will lead to a fuller realization of the economic importance of the fishery resources to the State. For this reason, it has been the special aim to make the report useful to all the fishing interests of the State. No essential technical considerations have been slighted but the scientific treatment has been adapted to the needs of fishermen and others who have had no opportunity to study ichthyology. It is most desirable that there be created a deeper interest in the welfare of both fishes and fishermen and a better understanding of the conditions and needs of the fishing industry with a view of placing this important branch on a permanent basis and making it yield an increasing revenue to both State and people. This volume will also be of interest to the layman and perhaps of special interest to the angler, as he will be able to make use of the work in the identification of species. As the scientific aspects of the subject have not been neglected, the work will also be found to have a value to ichthyologists and zoologists in general.

As a means of identifying any fish that may be taken in any waters of the State, artificial keys have been prepared based on the external characters that commercial fishermen and anglers may readily appreciate and, further, there is a copious index of common names which gives a further clue to all the species whose size makes them objects of capture.

As Dr. Smith states: "Although the fish life of North Carolina is not of a new or distinctive type and bears a rather close resemblance to that of the adjoining States, it does nevertheless have some features of exceptional interest."

On account of the great variation in the topography of the State, the number, length and volume of the rivers and streams, the large, shallow sounds which fringe the coast, the long coast-line, and the wide variation in climatic conditions, there has been developed in North Carolina a fish fauna rich in both species and individuals. Some of the species found in North Carolina are peculiar to this State, while others which were first identified in this State, have later been found elsewhere. Other species exist in much greater abundance in this State than in others.

Among the more prominent features of the fish fauna in North Carolina, Dr. Smith mentions the following:

"(a) The abundance of certain anadromous fishes, whose numbers are scarcely surpassed in any other waters, the chief of these being the shad, the alewives, and the striped bass.

"(b) The variety and abundance of suckers, minnows, and sun-fishes in the fresh waters generally, and of darters in the headwaters of the streams on both sides of the Alleghanies.

"(c) The occurrence in the sounds and along the outer shores of immense schools of mullet, squeteague, menhaden, blue-fish, croaker, spot, pig-fish, pin-fish and other food fishes.

"(d) The extension to the North Carolina coast of many species which are characteristic of the West Indies or Florida.

"(e) A few species of the Atlantic coast reach their southern limit in North Carolina (such as the cod and tautog) or

FISHES FIRST DESCRIBED FROM NORTH CAROLINA WATERS

PRESENT IDENTIFICATION	ORIGINAL NAME	COMMON NAME	TYPE LOCALITY	DESCRIBED YEAR
SILURIDÆ:				
<i>Schilbeodes furiosus</i> *	<i>Noturus furiosus</i>	Mad-tom; Tabby-cat	Neuse River	Jordan & 1889
CATOSTOMIDÆ:				
<i>Moxostoma papillosum</i>	<i>Ptychostomus papillosum</i>	Red horse; Shiner; White mullet	Catawba and Yadkin rivers	Cope, 1870
<i>Moxostoma collapseum</i> *	<i>Ptychostomus collapseus</i>	Suckling mullet; Small-mouth Red horse	Neuse, Yadkin and Catawba rivers	Cope, 1870
<i>Moxostoma pidiense</i> *	<i>Ptychostomus pidiensis</i>	Sucker	Yadkin River	Cope, 1870
<i>Moxostoma coregonus</i> *	<i>Ptychostomus coregonus</i>	Blue mullet	Catawba and Yadkin rivers	Cope, 1870
<i>Moxostoma album</i> *	<i>Ptychostomus albus</i>	White mullet	Catawba River	Cope, 1870
<i>Moxostoma thalassinum</i> *	<i>Ptychostomus thalassinus</i>	Sucker	Yadkin River	Cope, 1870
<i>Moxostoma robustum</i> *	<i>Ptychostomus robustus</i>	Red horse	Yadkin River	Cope, 1870
<i>Moxostoma crassilabre</i> *	<i>Ptychostomus crassilabris</i>	Mullet; Red horse; Red horse-mullet; Sucker-mullet; Golden mullet; Golden-finned mullet; Horse-fish Red fin; Trout-Sucker	Yadkin River	Cope, 1870
<i>Moxostoma conus</i> *	<i>Ptychostomus conus</i>	Sucker	Yadkin River	Cope, 1870
<i>Moxostoma rupiscartes</i>	<i>Moxostoma rupiscartes</i>	Jumping mullet; Jump-rocks	Catawba River	Jordan & 1889
CYPRINIDÆ:				
<i>Notropis pyrrhomelas</i>	<i>Photogenis pyrrhomelas</i>	Flery black minnow	Catawba River	Cope, 1870
<i>Notropis niveus</i>	<i>Hybopsis niveus</i>	Shiner; snowy minnow	Catawba River	Cope, 1870
<i>Notropis chlorocephalus</i>	<i>Hybopsis chlorocephalus</i>	Green-headed minnow	Catawba River	Cope, 1870
<i>Notropis brimleyi</i> *	<i>Notropis brimleyi</i>	Brimley's minnow	Cane River	Bean, 1908
<i>Notropis chiliticus</i> *	<i>Hybopsis chiliticus</i>	Red-lipped minnow	Yadkin River	Cope, 1870
<i>Notropis altipinnis</i> *	<i>Alburnellus altipinnis</i>	High-finned minnow	Yadkin River	Cope, 1870
<i>Notropis umbratilis matutinus</i> *	<i>Alburnellus matutinus</i>	Minnow	Neuse River	Cope, 1870
<i>Hybopsis labrosus</i>	<i>Ceraticthys labrosus</i>	Thick-lipped minnow	Catawba River	Cope, 1870
<i>Hybopsis hysinotus</i>	<i>Ceraticthys hysinotus</i>	High-backed minnow	Catawba River	Cope, 1870
POECILIDÆ:				
<i>Fundulus rathbuni</i> *	<i>Fundulus rathbuni</i>	Rathburn's killifish	Cape Fear River	Jordan & 1889
EXOCOETIDÆ:				
<i>Cypselurus lutkeni</i> *	<i>Exocoetus lutkeni</i>	Flying fish	Beaufort	Jordan & mann,
PERCIDÆ:				
<i>Boleostoma maculatiiceps</i>	<i>Boleostoma maculatiiceps</i>	Spotted-head darter	Catawba River	Cope, 1870
<i>Etheostoma ruflinestum</i>	<i>Poecilichthys ruflinestum</i>	Red-lined darter	French Broad River	Cope, 1870
<i>Etheostoma swannanoa</i>	<i>Etheostoma swannanoa</i>	Swannanoa darter	Swannanoa River	Jordan & mann,
<i>Etheostoma vulneratum</i>	<i>Poecilichthys vulneratus</i>	Red-spotted darter	French Broad River	Cope, 1870
<i>Ioa vitrea</i>	<i>Poecilichthys vitreus</i>	Glassy darter	Neuse River	Cope, 1870
TRIGLIDÆ:				
<i>Prionotus scitulus</i>	<i>Prionotus scitulus</i>	Slim-flying trad; Flying fish; Flying trad; sea robin	Beaufort	Jordan & 1882
GobiIDÆ:				
<i>Microgobius holmesii</i> *	<i>Microgobius holmesii</i>	Holm's Goby	Beaufort	Smith, 1907

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do not occur in noteworthy numbers further south (such as the white perch and striped bass)."

There have thus far been described from North Carolina waters 345 different species of fish; one species of lancelet; and one of lamprey. This number includes several species that have been introduced into the waters of North Carolina but which have become more or less established. Of these, 209 are marine or brackish water species; 125 are fresh water species; and 11 are anadromous or catadromous species.

Of this number, 29 species of fish were first described from North Carolina waters, of which 18 have as yet been found in no other State. These species are given in the following table together with the name of the species as described in the volume, name under which it was first described, the common name, type, locality, and the person by whom named and the date when the species was established. Those species marked by an asterisk have not been found as yet in any other State.

Under the heading of Systematic Catalogue of North Carolina fishes there is given a full list of all the species of fishes known to inhabit the fresh or salt waters of North Carolina and under each species there is given its technical name and original describer, its popular names, a brief synonymy, a diagnostic description and then a general account of their distribution, abundance, size, habits, food value, economic importance, etc., which have special reference to North Carolina. As an aid to the diagnostic description, a figure is given which shows the parts referred to and the names which designate them (Fig. 1)

Of the three great classes into which fishes and fish-like animals are divided, only the third is important in connection with the fishes of North Carolina, as the first two classes contain only one representative each. These classes are as follows:

KEY TO THE CLASSES OF FISHES AND FISH-LIKE ANIMALS

i. Animals with cartilaginous skeleton and without brain or skull; fins rudimentary and only on median line of body; mouth a slit surrounded by bristles; heart a tubular vessel without separate chambers; blood colorless; gillslits numerous, the respiratory cavity opening into the abdomen; inspired water discharged through a special abdominal pore.

LEPTOCARDII (lancelets).

ii. Animals with cartilaginous or bony skeleton; skull and brain present; heart developed as a cavity with at least two chambers; blood red.

a. Eel-shaped; skeleton cartilaginous; skull imperfect; mouth circular, suctorial; no jaws or paired fins; a single median nostril; gills pouch-shaped and numerous; skin naked; alimentary canal straight, without coeca; pancreas and spleen absent.

MARSIPOBRANCHII (lampreys, etc.)

aa. Skull well-developed; jaws distinct; fins usually highly-developed, some of them paired; skin usually scaly; nostrils at least two, not median; gill-openings a single slit on each side in most fishes (numerous in a few families); alimentary canal more or less convoluted; pancreas and spleen present.

PISCES (fishes).

Of the third class, Pisces, the North Carolina representatives fall into two easily recognized groups or sub-classes: (1) the Shark, Skates and Rays and (2) the True Fishes, which are distinguished anatomically as follows:

1. Skeleton cartilaginous; skull without sutures and without membranous bones; gill openings numerous (5 to 7) and slit like, the gills attached to the skin; tail heterocercal; skin tough, naked or covered with small rough scales, spines, or tubercles; air-bladder absent; jaws separable from skull; species viviparous or ovoviviparous, the eggs large and few in number; embryo with deciduous external gills.

SELACHII or ELASMOBRANCHII (sharks, skates, rays, etc.)

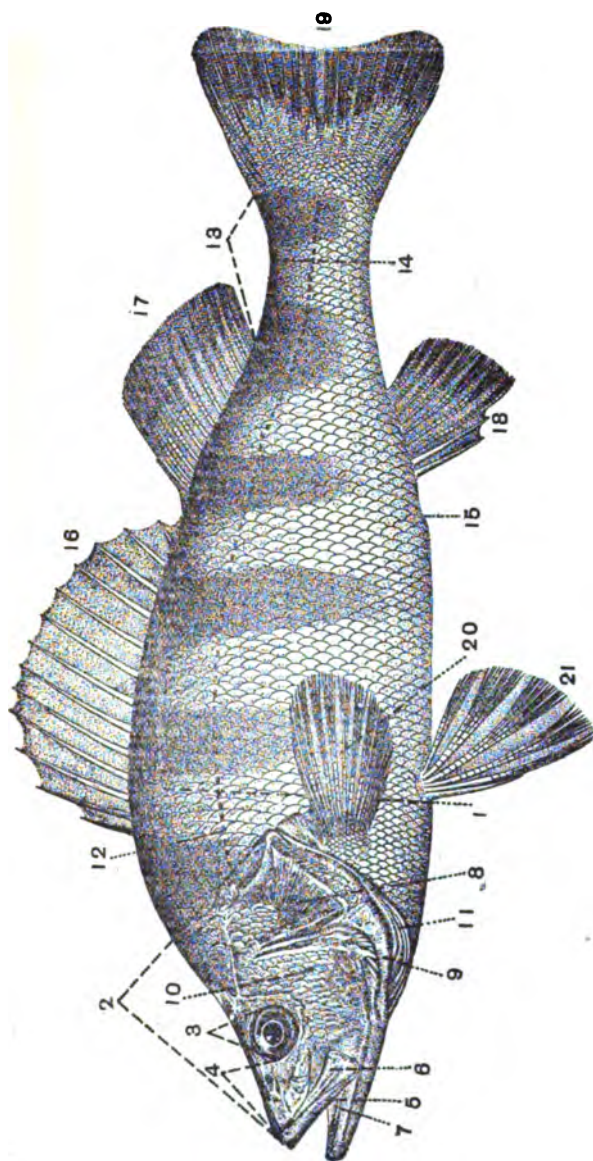


Fig. 1. CUT OF YELLOW PERCH SHOWING PARTS USUALLY REFERRED TO IN DESCRIPTIONS

- | | | |
|-----------------|-------------------------------|------------------------|
| 1. Depth | 8. Opercle | 15. Vent |
| 2. Head | 9. Subopercle | 16. Spinous dorsal fin |
| 3. Eye | 10. Preopercle and cheek | 17. Soft dorsal fin |
| 4. Snout | 11. Branchiostegals | 18. Anal fin |
| 5. Premaxillary | 12. Lateral line | 19. Caudal fin |
| 6. Maxillary | 13. Length of caudal peduncle | 20. Pectoral fin |
| 7. Lower Jaw | 14. Depth of caudal peduncle | 21. Ventral fin |

ii. Skeleton bony in all but a few families; skull with sutures and membranous bones (opercula, etc.); gill-openings a single slit on each side, the gills attached to bony arches; tail heterocercal or homocercal; body usually covered with numerous flat scales; air-bladder present or absent; jaws not distinct from the skull; species oviparous (exceptionally viviparous), the ova small and numerous.

TELEOSTOMI (true fishes).

In the first class are included 9 species of shark and 11 species of rays. In the second class (true fishes) there are 325 species. The 12 largest families included in these are as follows:

Cat-fishes		12	species	in	4	genera.
Suckers		18	"	"	5	"
Minnows		36	"	"	9	"
Killi-fishes		9	"	"	5	"
Mackerels		8	"	"	6	"
Carangids		17	"	"	8	"
Sun-fishes		17	"	"	10	"
Perches		24	"	"	12	"
Sea basses		11	"	"	7	"
Sparids		7	"	"	6	"
Drums		14	"	"	10	"
Flounders		11	"	"	7	"

The fisheries of North Carolina are of considerable economic importance to the State, approximating in value \$2,000,000 per year, the catch being utilized largely for food purposes. Of the 347 species listed, there are about 90 that are of present commercial value, most of which are used for food. In the following table there is given a list of those that are used for this purpose. In this table there is given the common as well as the scientific name.

FISHES USED FOR FOOD IN NORTH CAROLINA.

Sturgeon (*Acipenser oxyrhynchus*).

Suckers (Family Catostomidae. North Carolina has more species of suckers than any other State; 8 species used as food).

Red Horse (*Moxostoma Crassilabre*).

Choly; shiner (*Hybognathus Nuchalis*).

Horned dace (*Semotilus Atromaculatus*).

Roach; shiner (*Notemigonus Crysoleucas*).

Carp (*Cyprinus Carpio*).

Eel, fresh-water eel (*Anguilla Chrisypa*).

Sea Herring (*Clupda Harengus Linnaeus*).

Hickory Shad (*Pomolobus Mediocris*).

Branch Herring, Alewife (*Pomolobus Pseudoharengus*).

Glut Herring, Shoal Herring (*Pomolobus Aestivalis*).

Shad (*Alosa Sapidissima*).

Menhaden (*Brevoortia Tyrannus*).

Brook Trout; Mountain Trout (*Salvelinus Fontinalis*).

Rainbow Trout; California Trout (*Salmo Irideus*).

Pike; Pickerel (*Esox Americanus* and *Esox Reticulatus*).

Mullets (*Mugil Cephalus* and *Mugil Curema*).

Bonito (*Sarda Sarda*) variety of mackerel.

Spanish Mackerel (*Scomberomorus Maculatus*).

Cero (*Scomberomorus Regalis* and *Cavalla*).

Sword-fish (*Xiphias Gladius*).

Pompano; Sun-fish (*Trachinotus Carolinus*).

Blue-fish (*Pomatomus Saltatrix*).

Cabio; Crab-eater (*Rachycentron Canadus*).

Star, Harvest-fish (*Peprilus Alepidotus*).

Butter-fish (*Poronotus Tricanthus*).

Calico Bass; Speckled Perch (*Pomoxis Sparoides*).

Flier (*Centrarcus Macropterus*).

Rock Bass (*Ambloplites Rupestris*).

Goggle-eyes; Warmouth (*Chaenobryttus Gulosus*).

Long-eared Sun-fish; Red-belly; Robin (*Lepomis Auritus*).

Blud Joe; Blue-gills; Blue Sun-fish (*Lepomis Incisor*).

Holbrook's Sun-fish (*Lepomis Holbrooki*).

Sand Perch; Pumpkin-seed (*Lepomis Gibbosus*).
Black Bass; small mouthed (*Micropterus Dolomien*).
Black Bass, large mouthed (*Micropterus Salmoides*).
Pike Perch; Wall-eyed Pike (*Stizostedion Vitreum*).
Yellow Perch; Red-fin (*Perca Flavescens*).
Striped Bass; Rock-fish (*Roccus Lineatus*).
White Perch (*Marone Americana*).
Black-fish; Sea Bass (*Centropristes Striatus*).
Pig-fish; Hog-fish (*Orthopristis Chrysopterus*).
Snapper; Grunt (*Hæmulon Plumieri*).
Scup; Pin-fish (*Stenotomus Chrysops*).
Sailsois choice; Robin (*Lagodon Rhomboides*).
Sheepshead (*Archosargus Probatocephalus*).
Squeteague; Weak-fish; Sea Trout (*Cynoscion Regalis*).
Spotted Squeteague; spotted Weak-fish (*Cynoscion Nebulosus*).
Yellow Tail; Sand Perch; Perch (*Bairdiella Chrysura*).
Spot (*Leiostomus Xanthurus*).
Croaker (*Micropogon Undulatus*).
Red Drum; Red-fish (*Sciaenops Ocellatus*).
King-fish; Sea Mullet; Carolina Whiting (*Menticirrhus Americanus*).
Sea Mullet; King-fish (*Menticirrhus Saxatilis*).
Surf Whiting (*Menticirrhus Littoralis*).
Black Drum (*Pogonias Cromis*).
Oyster-fish; Tautog (*Tautoga Onitis*).
Porgee, Spade-fish (*Chaetodipterus Faber*).
Cod (*Gadus Callarias*).
Flounder; Summer Flounder; Plaice (*Paralichthys Dentatus*).
Flounder, Southern, (*Paralichthys Lethostigmus*).
Flounder (*Paralichthys Albiguttus*).

All the fishes mentioned in this list are found to a greater or less extent in the markets, but only a few of them are of any large economic value to the State. Of the migratory fishes, the most conspicuous and the ones of most value are

the shad, alewives, hickory shad, striped bass, white perch, eel and sturgeon. Of the salt water fishes would be included the mullets, squeteagues, Spanish mackerel, croaker, spot and menhaden. The principal fresh water fish is the large-mouthed black bass. The spotted squeteague, pig fish, hickory shad and black bass are taken in larger quantities in North Carolina than in any other State.

On account, however, of over-fishing and non-enforcement of present laws relating to the fisheries, the industries are deteriorating and in some instances quite rapidly. Unless the State will provide prompt and adequate protection to the shad, alewives, striped bass and other species which are beginning to show a decrease in abundance, they will soon share the same fate as the sturgeon.

There is no reason why the fisheries of North Carolina should not be maintained for an indefinite period and even be very greatly improved; and to this end the session of the Legislature of 1907 created a Fish Commission, but with very limited powers. It is to be hoped that at the session of 1909 the powers of the Fish Commission will be increased so that it will be in a position to prevent the causes of decline in these industries and be able to utilize all resources for building up and increasing the abundance of fish.

The Geological and Economic Survey, in cooperation with the United States Bureau of Fisheries, has carried on certain lines of work in regard to the protection and reproduction of the fishes of North Carolina, conducted through the Biological Laboratory at Beaufort, the hatchery at Edenton and the temporary hatching stations near Weldon. A number of fish have been introduced into the waters of North Carolina, some of which have become widely distributed and firmly established, such as the rainbow or California trout and the carp.

Large numbers of native fishes from outside hatcheries have been planted in the State, among these being the brook trout, large-mouthed and small-mouthed black basses, various sun-fishes, and several kinds of cat fishes.

REVIEWS

Van Nostrand's Chemical Annual, 1907. First Year of Issue. Edited by John C. Olsen, A. M., Ph. D. New York, D. Van Nostrand Co. x - 496 pp. The "Chemiker Kalendar" has long been a most useful publication but American chemists have desired a similar publication in English. In the new Annual Professor Olsen has improved upon the German model and produced an extremely satisfactory reference work. It consists exclusively of tables of physical and chemical data and lists of publications. The physical constants of inorganic and organic compounds are given in two tables, comprising nearly one half of the book. It is a pleasure to find frequently definite values for solubilities. The "Review of Chemical Literature" consists of a classified list of the more important articles published in the Journals and also a classified list of books; the time covered being from Jan. 1, 1905 to June 1, 1906. It is cause for congratulation that Professor Olsen undertook the editorship of a book which is so indispensable to the chemist. The execution of the mechanical part is excellent. A. S. W.

Solubilities of Inorganic and Organic Substances. A hand-book of the most reliable quantitative solubility determinations. Recalculated and compiled by Atherton Seidell. 8vo X - 367 pp. D. Van Nostrand Company. New York, 1907. The only dictionary of chemical solubilities has been Comey's which was published in 1894. Although it is a book of great value there are several defects which detract from its usefulness. It contains no organic substances but we find instead a great variety of rare inorganic double salts. Too many unreliable determinations are incorporated and the arrangement is not consistent throughout so that it is fre-

quently troublesome to locate a compound. Seidell has introduced a large number of important organic substances, the selection of inorganic compounds is more satisfactory, the arrangement is logical throughout, and the determinations are more reliable. Greater reliability was arrived at with much labor by recalculating the various determinations to a common basis and drawing curves through the points plotted. Selections were then made after comparing the curves and studying the methods of determination. An index adds to the value of the book. Every chemist should have access to this thoroughly satisfactory dictionary, in fact it should be in every working scientific library. A. S. W.

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